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UNITED STATES PARTICIPATION
in the
INTERNATIONAL INDIAN OCEAN EXPEDITION
and the
INTERNATIONAL COOPERATIVE INVESTIGATIONS OF THE TROPICAL ATLANTIC

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COLLECTION

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by

THE INTERAGENCY COMMITTEE ON OCEANOGRAPHY

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FOREWORD

A common interest in the seas is helping unite the nations of the world. This international unity in oceanography is expressed through cooperative research projects, through exchange of data, and most dramatically through jointly conducted expeditions. At the basis of this unity is the conviction that nations which plan together, work together, and share together the fruits of their common efforts, must inevitably become better neighbors.

It is this maritime togetherness which the Intergovernmental Oceanographic Commission seeks to promote by means of international cooperative programs. Two of the largest and most successful are the International Indian Ocean Expedition (IIOE) and the International Cooperative Investigations of the Tropical Atlantic (ICITA). Both programs have already made significant contributions to our knowledge of these two large but relatively unexplored bodies of water. In addition to stimulating basic science, the thirty nations participating in these investigations expect their cooperative efforts to lead to more productive exploitation of the living and mineral resources of the world ocean. This work also promises to increase our understanding of air/sea relationships and thus improve our ability to forecast and predict weather conditions.

In issuing this special supplement to its Fiscal Year 1965 National Oceanographic Program, the Interagency Committee on Oceanography seeks to accomplish three purposes:

(1) Provide background on the organization and broad objectives of the IIOE and ICITA.

(2) Identify the U.S. agencies and institutions conducting or supporting research in both programs.

(3) Describe the work of each institution in terms of cruise areas, facilities and personnel committed, and specific research objectives.

It should be noted that this document <u>is not a report of research accomplishment</u>; this will be the subject of future publications. Rather, it is a report designed to keep the scientific community abreast of past, present and planned operations of U.S. institutions participating in these two important international oceanographic efforts.

I. INTRODUCTION

The recent growth of international cooperation in oceanography is largely due to the work of UNESCO and the Intergovernmental Oceanographic Commission (IOC). The Commission was launched under the auspices of UNESCO in 1960 and currently includes fifty member governments. The purpose of the Commission is to promote scientific investigation of the nature and resources of the world ocean through the concerted efforts of its members. IOC's recently drafted General Scientific Framework for World Ocean Study further emphasizes that "international cooperation in science is not an end in itself, but serves other ends. It should be undertaken only when the sum of scientific, political, and economic benefits exceeds the cost. These benefits cannot be separated in practice. Scientific cooperation will not be effective for any purpose unless it is good science, yet governments are unlikely to support it unless it serves economic and political purposes, as well as scientific ones."

In bringing together the oceanographers of many countries, IOC has focused attention on oceanographic problems individual nations are unable to solve alone. The Commission has also been concerned with international problems of data exchange, standardization of equipment, intercalibration of techniques, allocation of radio frequencies for oceanographic use, exchange of scientists, and other problems fundamental to successful international coordination and cooperation.

Indian Ocean

Although the Indian Ocean's 28,000,000 square miles cover more than 14 percent of the earth's surface, very little was known about the region prior to the initiation of the International Indian Ocean Expedition in 1960. The objective of the IIOE is to delineate the features of the Indian Ocean's topography, circulation, and the distribution of living organisms in its waters. This goal will be attained through the research efforts of 25 nations operating 44 vessels from 1962-1965. Of special interest to participating scientists: air/sea interaction; studies of the chemical properties of the ocean's water; investigation of marine life; and geological and geophysical studies of the ocean's basin.

The Executive Secretary of the Intergovernmental Oceanographic Commission has responsibility for coordinating the IIOE. Responsibility for the United States program has been assigned to the National Science Foundation. The U.S. effort on the IIOE amounts to approximately one third the total and has entailed 14 cruises to the area at an estimated cost through 1965 of $20,000,000.

In addition to using existing data centers such as the National Oceanographic Data Center, two international centers have been established during the IIOE: the International Meteorological Center, Bombay, India; and the Indian Ocean Biological Center, Ceylon, India. Both may become permanent establishments after completion of IIOE.

Tropical Atlantic

The area bounded by latitudes 20°N, 20°S and the coasts of South America and Africa covers over 7,000,000 square miles - more than twice the area of the continental United States. Although a number of physical, chemical, biological and fishery observations have been made and samples collected in tropical Atlantic waters since the turn of the century, the total available data are insufficient to describe the area adequately. In fact, between 1900 and 1960 fewer than 2,200 oceanographic stations had been made in the area. Prior to the present investigations there was an average of only one station per 250,000 square miles for the month of June (all years together), and one station per 18,000 square miles for February. So large was the task of collecting sufficient data to study the seasonal variations in tropical Atlantic waters that no one nation could hope to undertake this task in one year, except by assigning all, or most of its available marine scientists and research vessels. To carry out oceanographic studies on a quasi-synoptic basis international cooperation is therefore essential.

Toward this end the International Cooperative Investigations of the Tropical Atlantic were undertaken during 1963. Coordinated by the Intergovernmental Oceanographic Commission, the objective of the ICITA is the detailed investigation of the marine environment of the Tropical Atlantic on a semi-synoptic basis to assure more efficient exploitation of its abundant fisheries

resources. Field operations commencing in 1963 have been named EQUALANT I (February-April 1963), EQUALANT II (August-September 1963) and EQUALANT III (February-March 1964). Fourteen vessels from seven nations participated in EQUALANT I; eleven vessels from eight nations in EQUALANT II; eight vessels from six nations in EQUALANT III. The Bureau of Commercial Fisheries has functioned as International Coordinator of the ICITA. Data resulting from the program are being processed by the National Oceanographic Data Center.

The total cost to the United States in the International Cooperative Investigations of the Tropical Atlantic has been about $3,000,000, all of which has come out of regularly sponsored programs.

UNITED STATES PARTICIPATION

in the

INTERNATIONAL INDIAN OCEAN EXPEDITION

by
John Lyman
Indian Ocean Coordinator
National Science Foundation

Revised March 15, 1964

A. ORGANIZATION AND HISTORY

The International Indian Ocean Expedition (IIOE) was conceived at the first meeting of the Special Committee on Oceanic Research (SCOR) of the International Council of Scientific Unions (ICSU) in September 1958. United States participation was initially planned by the Committee on Oceanography of the National Academy of Sciences (NASCO). The preliminary plan was presented to the Federal Council for Science and Technology in May 1960, and approval for United States participation was announced by the White House on June 13, 1960. Scientific responsibility for the United States participation was assigned to the National Academy of Sciences - National Research Council, and the National Science Foundation was directed to plan and coordinate Federal support for United States participation in the program.

At the request of the Director of the National Science Foundation, other Federal agencies with potential interest in the IIOE appointed representatives to serve as single points of contact and facilitate communication among the agencies. As a result of meetings of these representatives held during the summer of 1960, it was determined that the preliminary plans were inadequate to carry out the stated aims of the IIOE, particularly in the areas of biological oceanography and of air-sea interaction, and following international meetings held by SCOR at Copenhagen and Helsinki in July 1960, NASCO enlarged its Indian Ocean Expedition Panel, set up five Working Groups (Biology; Geology, Geophysics, and Bathymetry; Meterology; Physical and Chemical Oceanography; and Expedition Data) and drew up an enlarged program for U. S. participation.

During the spring of 1962, it was agreed between SCOR and the new International Oceanographic Commission (IOC) that henceforth the Secretary of IOC would have responsibility for coordination of the IIOE. At the same time NASCO, as the United States adhering body to SCOR, felt it inappropriate to continue to coordinate the United States participation in the IIOE. Full responsibility for the United States program was thus assumed by the National Science Foundation. The NASCO IIOE Panel was discontinued in April 1963.

B. FINANCIAL SUPPORT

The original Presidential Directive in June, 1960, provided that United States participation in the IIOE would be funded by normal budgetary process. Accordingly, the United States Navy, historically the chief Federal sponsor of basic research in oceanography through its Office of Naval Research, agreed to permit vessels whose operations it finances through research contracts at Scripps Institution of Oceanography, Woods Hole Oceanographic Institution and Lamont Geological Observatory to undertake cruises to the Indian Ocean. Data-processing facilities at the Navy Oceanographic Office were put at the disposal of the U. S. participants; Navy survey vessels in the Indian Ocean were assigned to make oceanographic observations in support of the IIOE.

The National Science Foundation, which supports research through grants made as the result of applications proposing specific research projects, encouraged United States research institutions to submit proposals for research connected with the IIOE, and took steps to augment its available research funds by including a special item for the IIOE, commencing with its Fiscal Year 1962 budget.

Other Federal agencies have been less successful in obtaining the additional funding required to permit them to operate themselves in the Indian Ocean or to support research there in fields related to their specific missions; the National Science Foundation has transferred funds to enable some of these agencies to carry out urgent programs related to the IIOE.

The following tabulation summarizes past and planned Federal support of the U. S. participation in the IIOE through Fiscal Year 1965:

THOUSANDS OF DOLLARS

Fiscal Year	1961	1962	1963	1964	1965
USN	693	230	958	803	250
NSF	-	2,117	4,420	4,500	3,500
Bureau of Commercial Fisheries	-	-	102	154	154
Weather Bureau	-	-	792	411	-
Coast & Geodetic Survey	-	-	-	200	-

C. SCIENTIFIC PROGRAM BY DISCIPLINES

The United States program for the IIOE, in accordance with the original stated aims of the expedition, is devoted to the scientific examination of four great areas of interest in the Indian Ocean.

1. The first of these concerns itself with the problems of why there is an ocean basin in the first place; what are the forces that have shaped and are continuing to shape the basin; what are the resemblances between this piece of the earth's crust and any other; and how is the basin of the Indian Ocean dissimilar from other ocean basins? The techniques used in attempting to answer these questions are primarily geophysical and geological, and they are being employed on expeditions sent out by the Scripps Institution of Oceanography, Lamont Geological Observatory, and Woods Hole Oceanographic Institution.

2. The second broad area of investigation involves the chemical and physical description of the waters of the Indian Ocean, and the study of their motions. Techniques used involve sampling of the water in predetermined patterns, with respect to the horizontal distribution and vertical spacing of samples; concurrent precise measurements of water temperature; subsequent chemical and isotopic analyses of the water samples; and determination of current flow at various depths by all possible means. All United States ships participating in the IIOE are equipped for such water sampling, and the direct measurement of current flow was the particular object of a University of Rhode Island expedition embarked in the Scripps Institution vessel ARGO (Knauss, 1961).

3. The third major field of interest is the living populations, plant and animal, of the Indian Ocean. All United States ships are equipped to sample plankton and to observe surface biological phenomena; some measure primary productivity. The research vessel ANTON BRUUN has biological oceanography as her primary mission. The Stanford University vessel TE VEGA is concentrating on biological and physiological studies of island groups and other shallow water areas.

4. The fourth main area of research is concerned with the interaction between the ocean and the atmosphere. Although several of the U. S. research vessels working in the Indian Ocean are equipped to make upper-air meteorological observations, the United States has the greater part of its meteorological effort based ashore. Meteorological aircraft of the U. S. Weather Bureau and of Woods Hole Oceanographic Institution, work in connection with the International Meteorological Center. IMC has been established with the assistance of the Government of India and the United Nations Special Fund. Meteorological satellites and buoys are also being operated in support of the program (Ramage, 1962).

D. SCIENTIFIC PROGRAMS OF INSTITUTIONS

As indicated above, research programs of all United States vessels participating in the IIOE contribute to at least two of the four fundamental areas of interest; many contribute to three; some to all four. For this reason, it is more practical to describe the programs in detail by setting forth the past, present, and planned cruises of each institution.

1. SCRIPPS INSTITUTION OF OCEANOGRAPHY

The Scripps Institution of Oceanography of the University of California at San Diego plans to undertake three major cruises to the Indian Ocean under the overall direction of Dr. Robert L. Fisher. The first of these, called MONSOON, was carried out by the research vesseL ARGO according to the following itinerary:

1960	Schedule	Program
19 October	ARGO left Darwin	Geological-geophysical exploration under Dr. R. L. Fisher. Emphasis on two-ship seismic refraction work between Darwin and Djakarta.
23 October	Joined by M/V MALITA	
13 November	MALITA detached	
14 November	ARGO arrived Djakarta	
18 November	ARGO left Djakarta	Same program, except for seismic refraction. Emphasis on heat flow, large-volume water-sampling; topography.
7 December	Arrived Mauritius	
10 December	Left Mauritius	

1961	Schedule	Program
2 January	Arrived Fremantle	Same
6 January	Left Fremantle	
15 January	Arrived Hobart	
17 January	Left Hobart	
22 January	Arrived Wellington	

The following observations were made between Darwin and Wellington:

Underway Observations:

Precision depth recordings	17,000 miles
Gravimeter recordings	15,500 miles
Towed proton precession magnetometer recordings	16,600 miles
Insect collection, nets on superstructure	13,800 miles
Bathythermograms	618
Surface water samples (for radio-caesium)	29

Station Operations

Seismic refraction stations	16
Gravity cores	48
Piston cores	6
Heat flow measurements by temperature probe	33
Hydrographic casts to bottom	18
Special 2-liter water samples	13 stations
Midwater trawl hauls	13
One-meter standard plankton tows	18
17 cm vertical microplankton hauls	49

Station Operations (Cont'd)

Bottom samples (biological)	7
Rock dredges	6
Large-volume water samples (C^{14} and trace elements)	18 stations
Bottom photography	18 stations

In addition, some seismic reflection shooting was carried out, occasional air samples were taken, gravity was measured in ports of call, rocks and biological specimens were collected in ports of call, and large organisms were dip-netted at light lures on most night stations.

The second Scripps cruise, called LUSIAD, was also carried out by the R/V ARGO, according to the following itinerary:

Arrived	1962	Sailed	Program
	Singapore	28 June	Studies of equatorial circulation during one monsoon season, under Dr. John Knauss. Hydrographic casts and direct current observations with the aid of anchored buoys.
24 July	Mombasa	28 July	
25 August	Colombo	28 August	
29 September	Cochin	4 October	In company R/V HORIZON: two-ship seismic refraction work under Drs. George C. Shor, R. W. Raitt, and R. L. Fisher. Bottom-sampling; hydrographic casts; heat-flow measurements. C^{14} collections under Dr. N. W. Rakestraw. Topography, magnetism, gravity, underway measurements; under Dr. R. L. Fisher.
26 October	Port Louis, Mau.	30 October	
28 November	Fremantle	2 December	
23 December	Port Darwin		

Arrived	1963	Sailed	Program
	Port Darwin	1 January	
18 January	Bali	18 January	
23 January	Djakarta	26 January	
12 February	Colombo	16 February	Repeat equatorial circulation during second monsoon under Drs. Knauss and Taft. Geological-Geochemical-geophysical observations under Drs. George Bien, John Belshe, and Charles Keeling.
16 March	Mombasa	23 March	
29 March	Seychelles	29 March	
12 April	Penang	17 April	
15 May	Mombasa	18 May	
28 May	Capetown		

The itinerary of the R/V HORIZON during LUSIAD was scheduled as follows:

Arrived	1962	Sailed	Program
	Suez	9 September	Conduct underway reflection pro-
20 September	Aden	21 September	filing of Red and Arabian Seas.
29 September	Cochin	4 October	In company R/V ARGO; two-ship
17 October	Seychelles	19 October	seismic refraction work under
26 October	Port Louis, Mau.	31 October	Drs. George G. Shor, R. W. Raitt, and R. L. Fisher, bottom-sampling,
28 November	Fremantle	3 December	hydrographic casts, heat-flow
23 December	Port Darwin		measurements.

Besides serving as consort to the R/V ARGO between Cochin and Port Darwin, the HORIZON carried out hydrographic and heat flow studies (von Herzen, 1963) between Suez and Cochin, and from Port Darwin she returned to San Diego via the Pacific. Figure 1 shows the track of MONSOON and Figures 2 to 4 that of LUSIAD.

The third planned Scripps cruise, Expedition DODO, will be carried out by the R/V ARGO between July and October 1964 under W. R. Riedel. Emphasis will be on detailed stratigraphic, geochemical, and heat flow development in the central and eastern Indian Ocean where earlier cruises have indicated areas of especial interest. Continuous underway magnetometer recordings will also be made.

LAMONT GEOLOGICAL OBSERVATORY

Three cruises of the R/V VEMA have been planned as part of the IIOE.

VEMA 16 Itinerary

Arrived	1959	Sailed
	Cape Town	27 December
1960		1960
22 January	Mauritius	25 January
22 February	Fremantle	26 February
14 March	Adelaide	16 March
31 March	Wellington	

Under the direction of C. Fray, as Chief Scientist, VEMA made the passage from Cape Town to Mauritius and from Mauritius to Fremantle. More than 8,300 miles of topographic track was recorded with a precision depth recorder in the southern Indian Ocean. The existence of a mid-ocean ridge and associated rift valley was verified by six crossings of this topographic feature (Ewing and Heezen, 1960). A towed magnetometer produced a continuous plot of the total intensity of the earth's magnetic field along the ship's track.

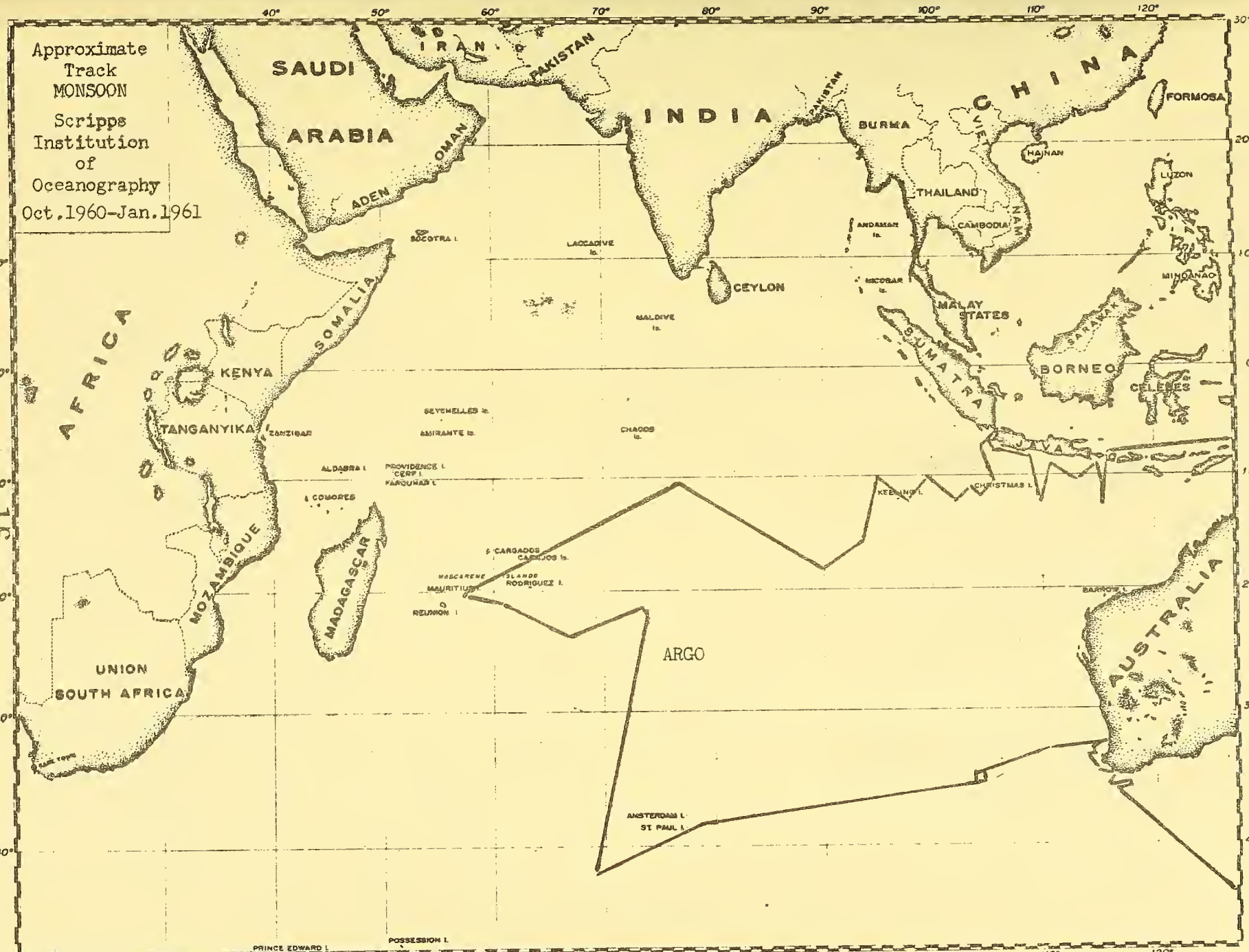

Approximate
Track
MONSOON
Scripps
Institution
of
Oceanography
Oct.1960-Jan.1961
SAUDI
ARABIA
IRAN
PAKISTAN
INDIA
CHINA
FORMOSA
BURMA
VIET
NAM
HAINAN
THAILAND
CAMBODIA
LUZON
MINDANAO
OMAN
ADEN
SOCOTRA I.
LACCADIVE Is.
ANDAMAN Is.
NICOBAR Is.
CEYLON
MALDIVE Is.
MALAY
STATES
SUMATRA
SARAWAK
BORNEO
CELEBES
JAVA
CHRISTMAS I.
KEELING I.
SOMALIA
AFRICA
KENYA
TANGANYIKA
ZANZIBAR
SEYCHELLES Is.
AMIRANTE Is.
CHAGOS Is.
ALDABRA I.
PROVIDENCE I.
CERP I.
FARQUHAR I.
COMORES
MOZAMBIQUE
MADAGASCAR
CARGADOS
CARAJOS Is.
MASCARENE
ISLANDS
MAURITIUS
RODRIGUEZ I.
REUNION I.
ARGO
BARROW I.
AUSTRALIA
UNION
SOUTH AFRICA
AMSTERDAM I.
ST. PAUL I.
PRINCE EDWARD I.
POSSESSION I.
40°
50°
60°
70°
80°
90°
100°
110°
120°
30°
20°
10°
0°
10°
20°
30°
40°

Figure 1.

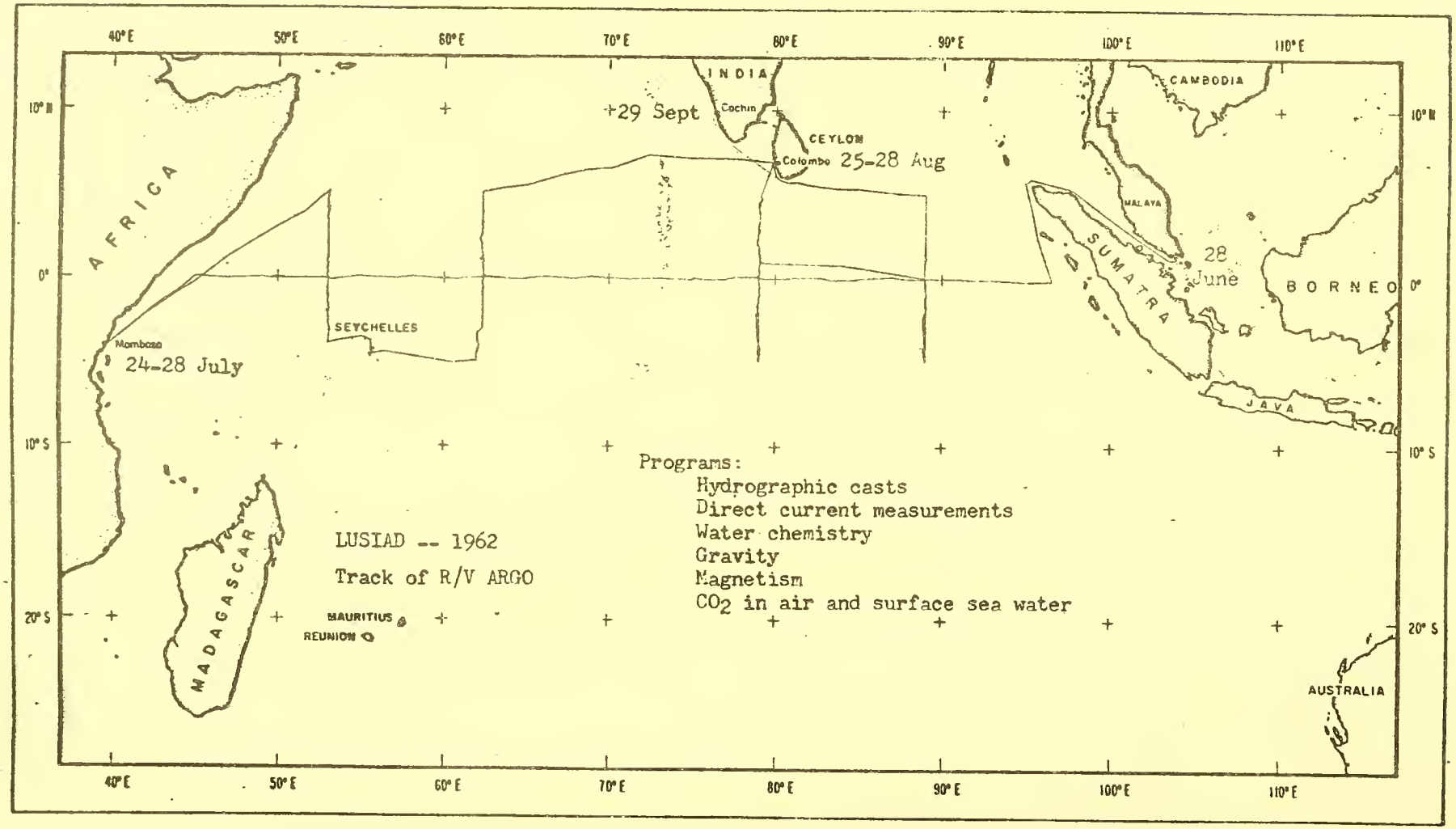

40°E
50°E
60°E
70°E
80°E
90°E
100°E
110°E
10°N
0°
10°S
20°S
AFRICA
INDIA
Cochin
CEYLON
Colombo
CAMBODIA
MALAYA
SUMATRA
BORNEO
JAVA
AUSTRALIA
SEYCHELLES
Mombasa
MADAGASCAR
MAURITIUS
REUNION
+29 Sept
25-28 Aug
28 June
24-28 July
LUSIAD -- 1962
Track of R/V ARGO
Programs:
Hydrographic casts
Direct current measurements
Water chemistry
Gravity
Magnetism
CO_2 in air and surface sea water

FIGURE 2

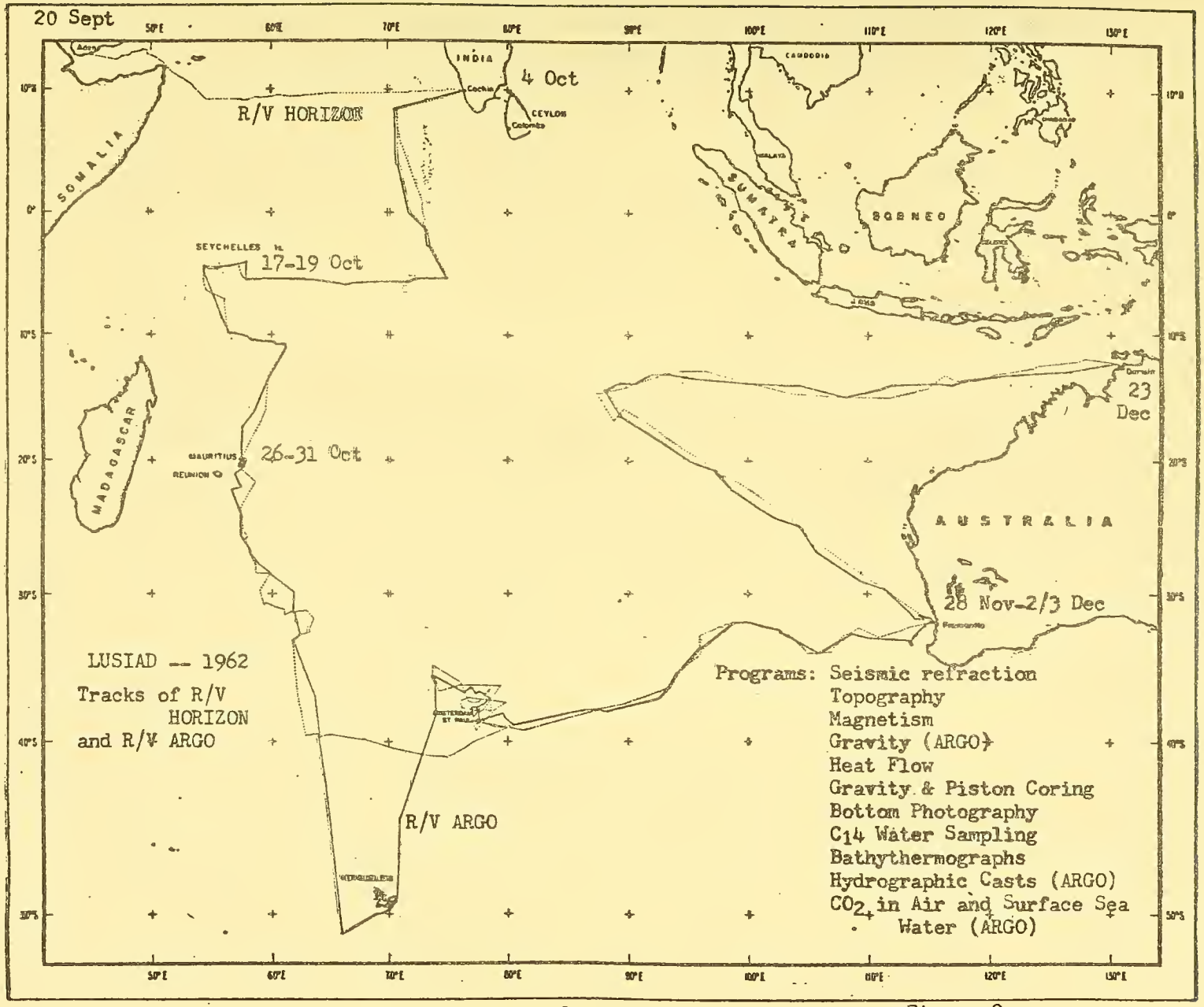

20 Sept
4 Oct
R/V HORIZON
INDIA
Cochin
CEYLON
Colombo
SOMALIA
SEYCHELLES
17-19 Oct
MADAGASCAR
MAURITIUS
REUNION
26-31 Oct
SUMATRA
BORNEO
AUSTRALIA
23 Dec
28 Nov-2/3 Dec
LUSIAD -- 1962
Tracks of R/V HORIZON and R/V ARGO
R/V ARGO
Programs: Seismic refraction
Topography
Magnetism
Gravity (ARGO)
Heat Flow
Gravity & Piston Coring
Bottom Photography
C14 Water Sampling
Bathythermographs
Hydrographic Casts (ARGO)
CO2 in Air and Surface Sea Water (ARGO)

Figure 3

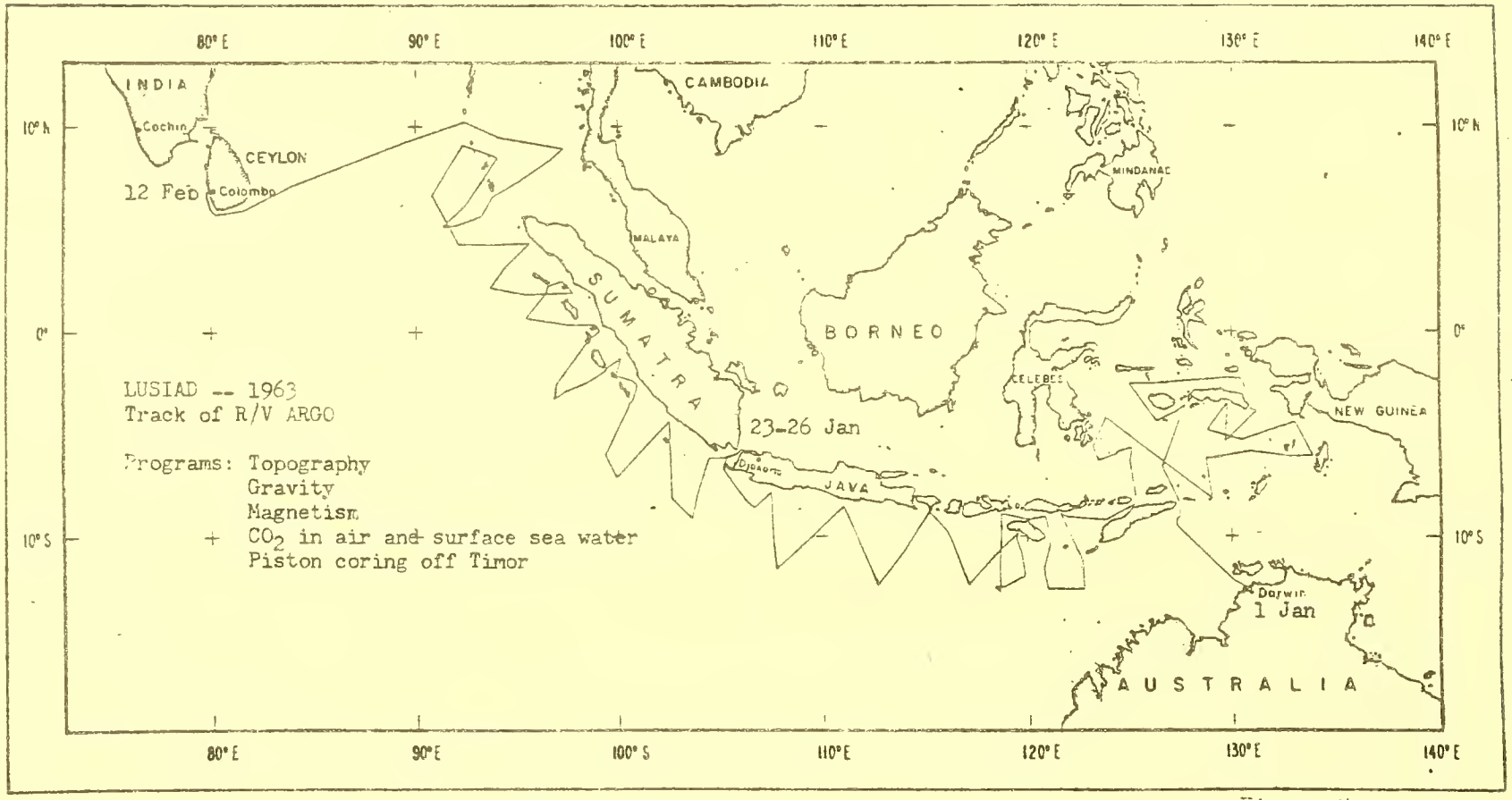

80° E
90° E
100° E
110° E
120° E
130° E
140° E
10° N
0°
10° S
INDIA
Cochin
CEYLON
Colombo
12 Feb
CAMBODIA
MALAYA
SUMATRA
BORNEO
MINDANAO
CELEBES
NEW GUINEA
23-26 Jan
Djakarta
JAVA
Darwin
1 Jan
AUSTRALIA
LUSIAD -- 1963
Track of R/V ARGO
Programs: Topography
Gravity
Magnetism
+ CO_2 in air and surface sea water
Piston coring off Timor

Figure 4

Forty-seven piston cores of the bottom sediment were obtained. Paleocene and Cretaceous deposits were found in two cases (Herman, 1963). Multiple photographs of the bottom were taken at 23 stations. Thirty hydrographic stations were occupied for serial observations of temperature, salinity, and oxygen. Sixteen large volume water samples, representative of all of the water masses, were collected for C-14 age determination. Biological collections included 11 bottom trawls and 80 plankton samples. Additional observations obtained included measurements of the heat flow through the ocean floor, and propagation of sound through the SOFAR channel.

Under the direction of John E. Nafe, as Chief Scientist, VEMA made passages from Fremantle to Adelaide and from Adelaide to Wellington. During the early part of this program seismic refraction measurements were undertaken in cooperation with HMAS DIAMANTINA. During the remainder of the passage the program of observations underway and at stations was closely similar to that of the Cape Town to Fremantle traverse. Figures 5 and 6 show tracks of VEMA-16.

VEMA 18 Itinerary Figure 7

Arrived	1962	Sailed	Chief Scientist
31 May	Cape Town	3 June	Manik Talwani
20 June	Port Louis	22 June	Marcus Langseth
12 July	Fremantle	14 July	
1 August	Wellington, N.Z.	5 August	

The underway program included continuous magnetic, topographic, gravity, and seismic reflection measurements. At the stations, cores and camera stations were the most common combinations, with more emphasis than usual being placed on plankton sampling. In the area south of Australia a number of bottom trawl stations were occupied. The passage from Bass to Wellington was begun about July 25th. Particular emphasis was placed on comparison of total sediment thickness with that found in the Atlantic Ocean.

VEMA 19 (1963)

The track of VEMA 19 (1963) is also shown in Figure 7.

The new R/V CONRAD, to be operated by Lamont Geological Observatory, will also spend three months in the Indian Ocean in 1963-64. (Figure 8)

During all VEMA cruises, the following program is being carried out under the supervision of the investigators named. Dr. Maurice Ewing is the principal investigator on all VEMA cruises.

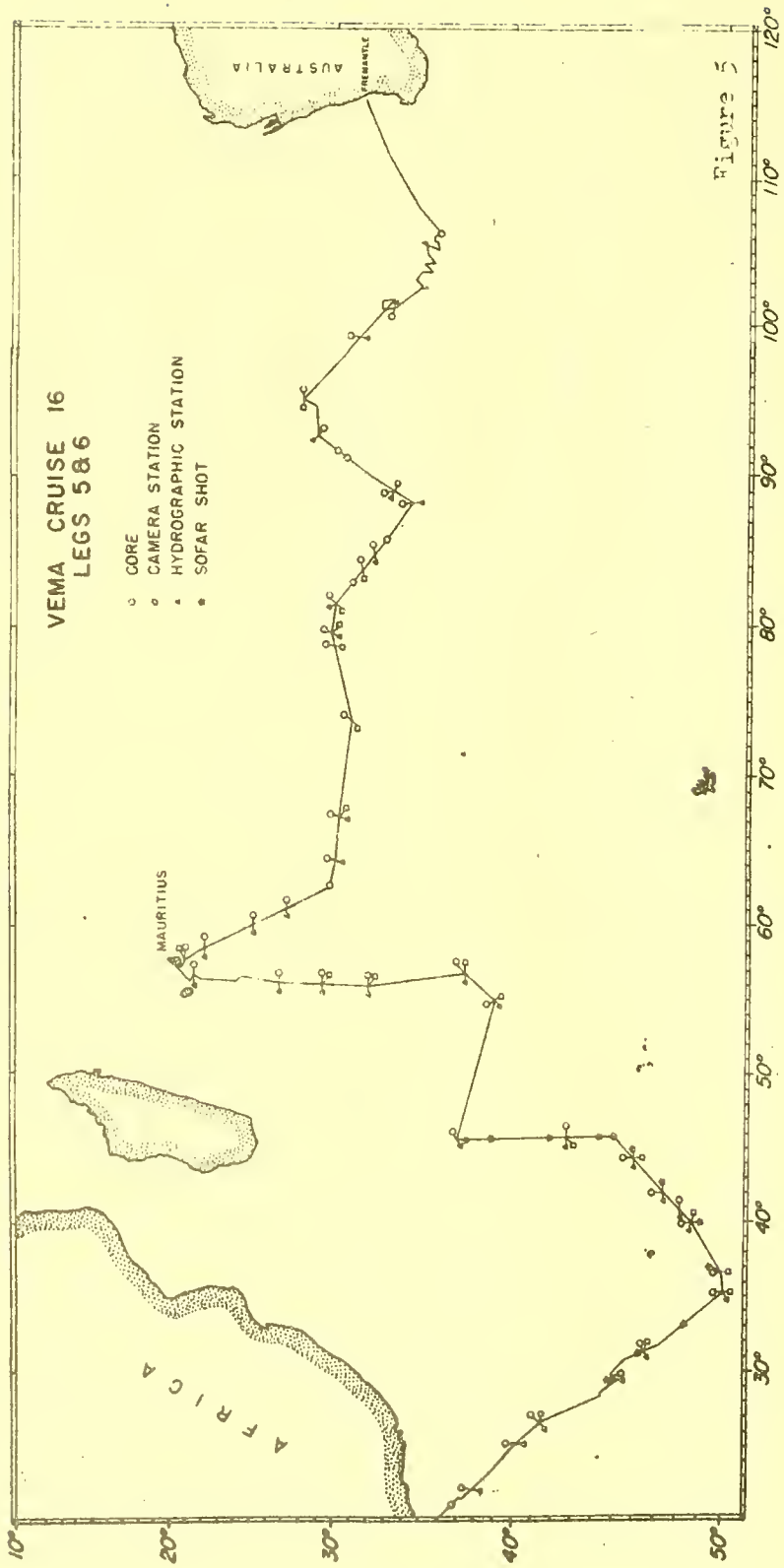

VEMA CRUISE 16
LEGS 5 & 6
CORE
CAMERA STATION
HYDROGRAPHIC STATION
SOFAR SHOT
AUSTRALIA
FREMANTLE
MAURITIUS
AFRICA
120°
110°
100°
90°
80°
70°
60°
50°
40°
30°
10°
20°
30°
40°
50°

Figure 5

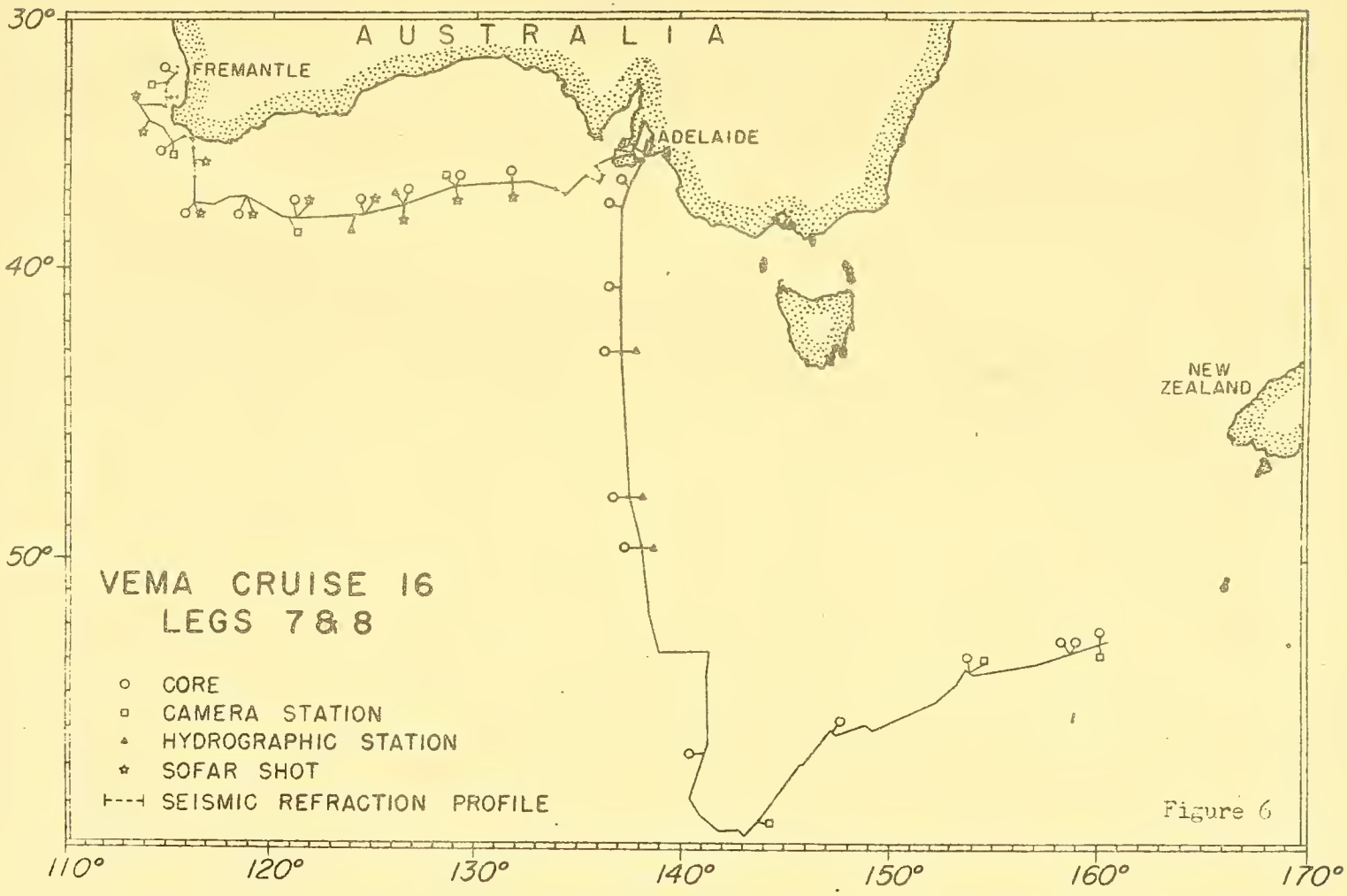

AUSTRALIA
FREMANTLE
ADELAIDE
NEW ZEALAND
30°
40°
50°
110°
120°
130°
140°
150°
160°
170°
VEMA CRUISE 16
LEGS 7 & 8
CORE
CAMERA STATION
HYDROGRAPHIC STATION
SOFAR SHOT
SEISMIC REFRACTION PROFILE

Figure 6

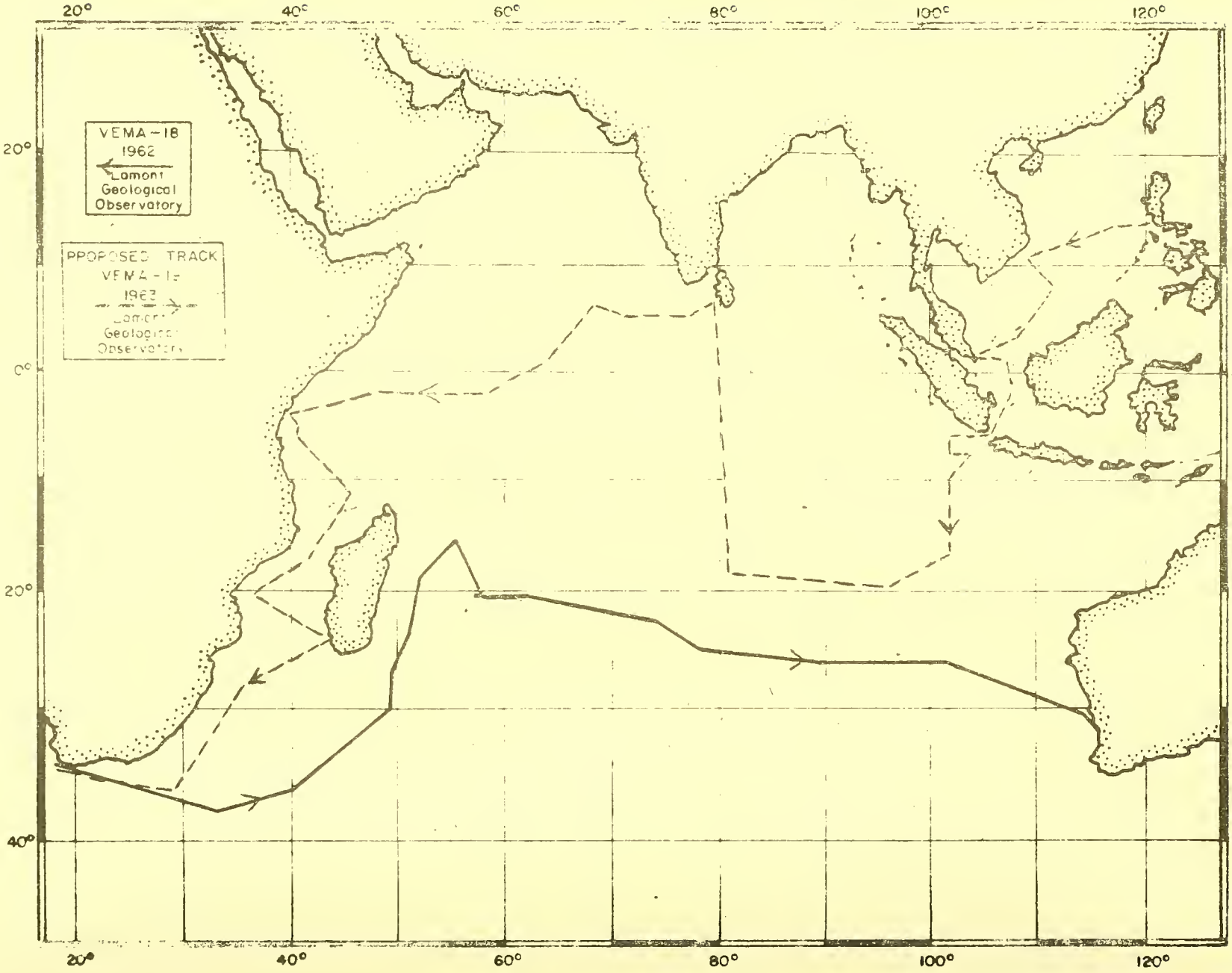

VEMA-18
1962
Lamont
Geological
Observatory
PROPOSED TRACK
VEMA-18
1963
Lamont
Geological
Observatory
20°
40°
60°
80°
100°
120°
20°
0°
20°
40°

Figure 7

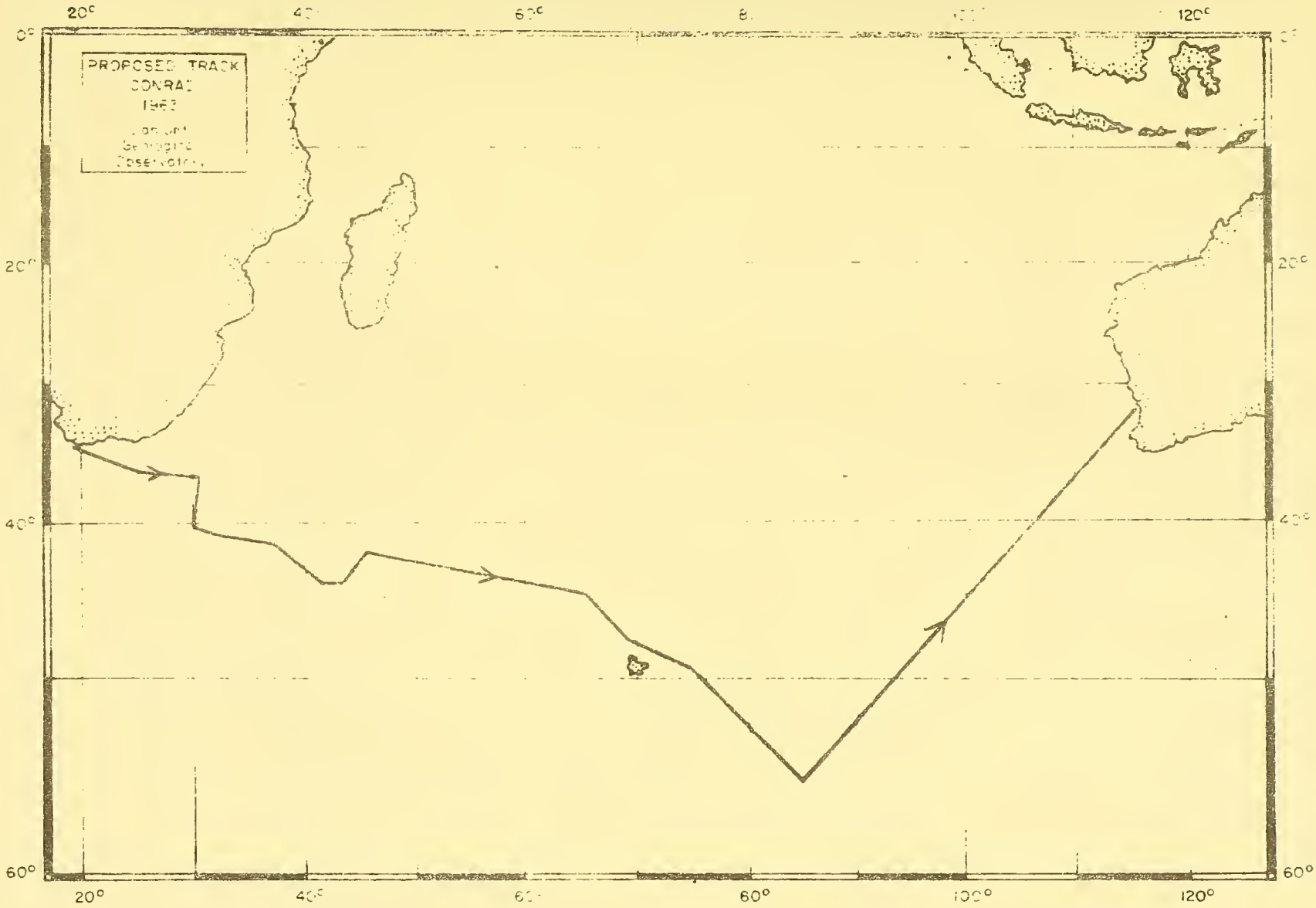


Figure 8

Underway Observations	Investigators
Precision depth recordings	Bruce Heezen
Gravimeter recordings	J. L. Worzel
Magnetometer total field intensity recordings	J. R. Heirtzler
Bathythermograms	R. Gerard
Seismic reflection	J. I. Ewing
Surface water temperature	M. Ewing

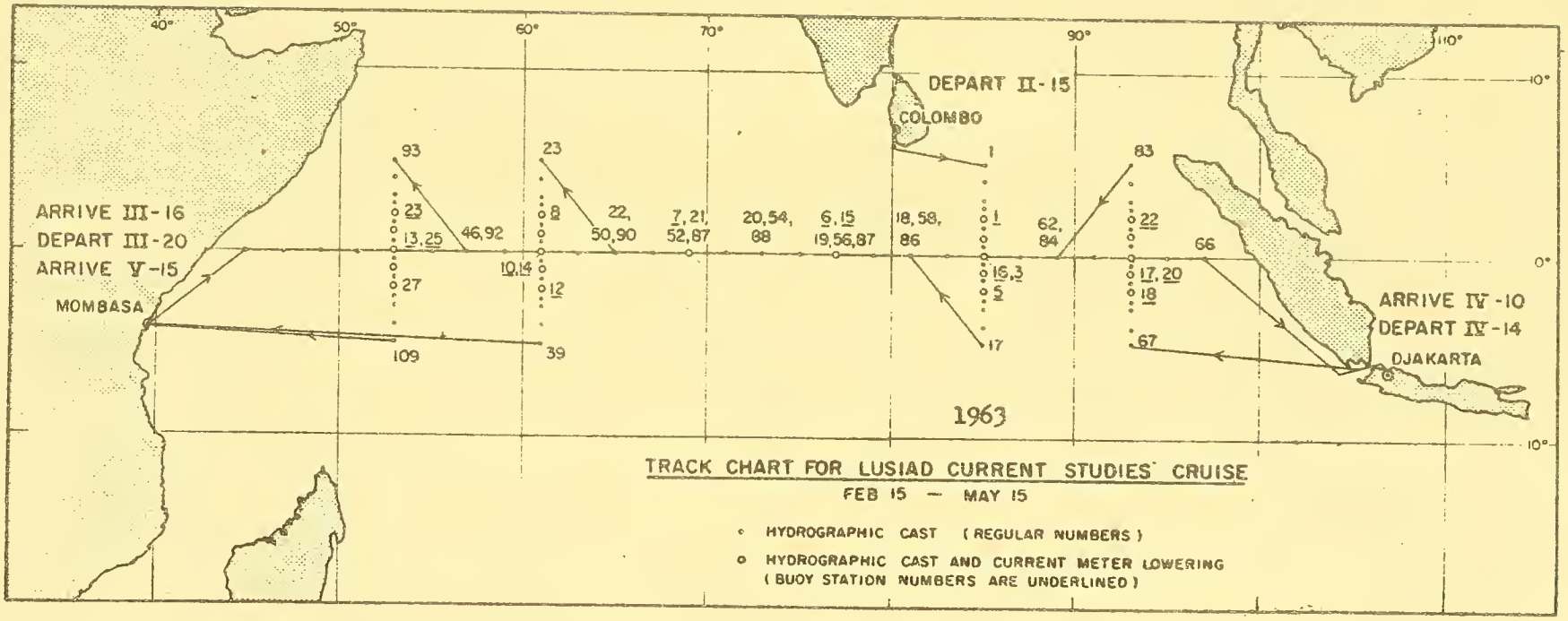
Station Operations	
Seismic refraction profiles	(Charles Drake (John Ewing (John Nafe

Underway Observations	
Gravity cores	C. Fray
Hydrographic casts	R. Gerard
Large-volume samples for C^{14}, H^3, Sr, Cs	W. Broecker
Microbiological sampling	P. R. Burkholder
Plankton sampling	Alan Bé
Bottom trawling for biological specimens	Alan Bé
Sound velocity and transmission measurements	John Ewing
Bottom temperatures and temperature gradients	M. Langseth
Bottom dredging for rocks	C. Fray
Bottom photography	M. Ewing

In Port Observations	
Rock collections	C. L. Drake

UNIVERSITY OF RHODE ISLAND

Under Dr. John A. Knauss, the Narragansett Marine Laboratory of the University of Rhode Island carried out two three-month studies of the equatorial current circulation in the Indian Ocean aboard the R/V ARGO, whose cruise itinerary has been given above. Planned locations of the sections are shown in Figure 9. Results have been reported by Knauss and Taft (1963, 1964).



TRACK CHART FOR LUSIAD CURRENT STUDIES' CRUISE

FEB 15 — MAY 15

• HYDROGRAPHIC CAST (REGULAR NUMBERS)

o HYDROGRAPHIC CAST AND CURRENT METER LOWERING (BUOY STATION NUMBERS ARE UNDERLINED)

WOODS HOLE OCEANOGRAPHIC INSTITUTION

The Woods Hole Oceanographic Institution, under the direction of Dr. Paul Fye, is conducting the following cruises to the Indian Ocean:

ATLANTIS II Itinerary - 1963

Arrived	Port	Sailed
	Woods Hole	5 July
13 July	Monaco	15 July
28 July	Aden	30 July (fuel)
9 August	Bombay	11 August
29 August	Colombo	31 August (fuel)
16 September	Zanzibar	18 September
24 September	Seychelles	26 September
10 October	Diego Suarez	10 October (fuel)
24 October	Mauritius	26 October
10 November	Lourenco Marques	12 November
20 November	Capetown	22 November (fuel)
20 December	Woods Hole	

Under the direction of A. R. Miller as Chief Scientist, the ATLANTIS II occupied 183 stations (Figure 10) in a detailed study of the Agulhas Current.

A cruise of the R/V CHAIN under the direction of Dr. J. B. Hersey is being conducted according to the following schedule (Figures 11 and 12):

Arrived	1964	Sail	Program
	Suez	18 March	Underway observations in Red Sea. Reconnaissance of Zebirget Island
25 March	Aden	28 March	Area I
13 April	Port Victoria	15 April	Area II
1 May	Port Louis	4/5 May	Area II or III
22 May	Port Victoria	25 May	Area II and underway observations
8 June	Suez		

The underway observations comprise readings of shipboard gravimeter, towed magnetometer, echo-sounder (bathymetry), sparker or boomer (continuous seismic profiling), and thermistor chain (continuous temperature recording).

In the Red Sea, the tracks cross and intercept the seismic refraction profiles made by the ATLANTIS and VEMA in 1958. Four or five heat flow measurements are planned.

SAUDI
ARABIA
INDIA
AFRICA
SEYCHELLES
MADAGASCAR
MAURITIUS
25°
20°
15°
10°
5°
0°
5°
10°
15°
20°
25°
30°
30°
35°
40°
45°
50°
55°
60°
65°
70°
75°
80°
40
45
50
55
60
65
70
75
80
82
85
90
95
100
105
110
115
120
125
130
135
140
145
150
155
160
165
170
175
180
185
190
195
200
205
210
215
220
225
230

Figure 10

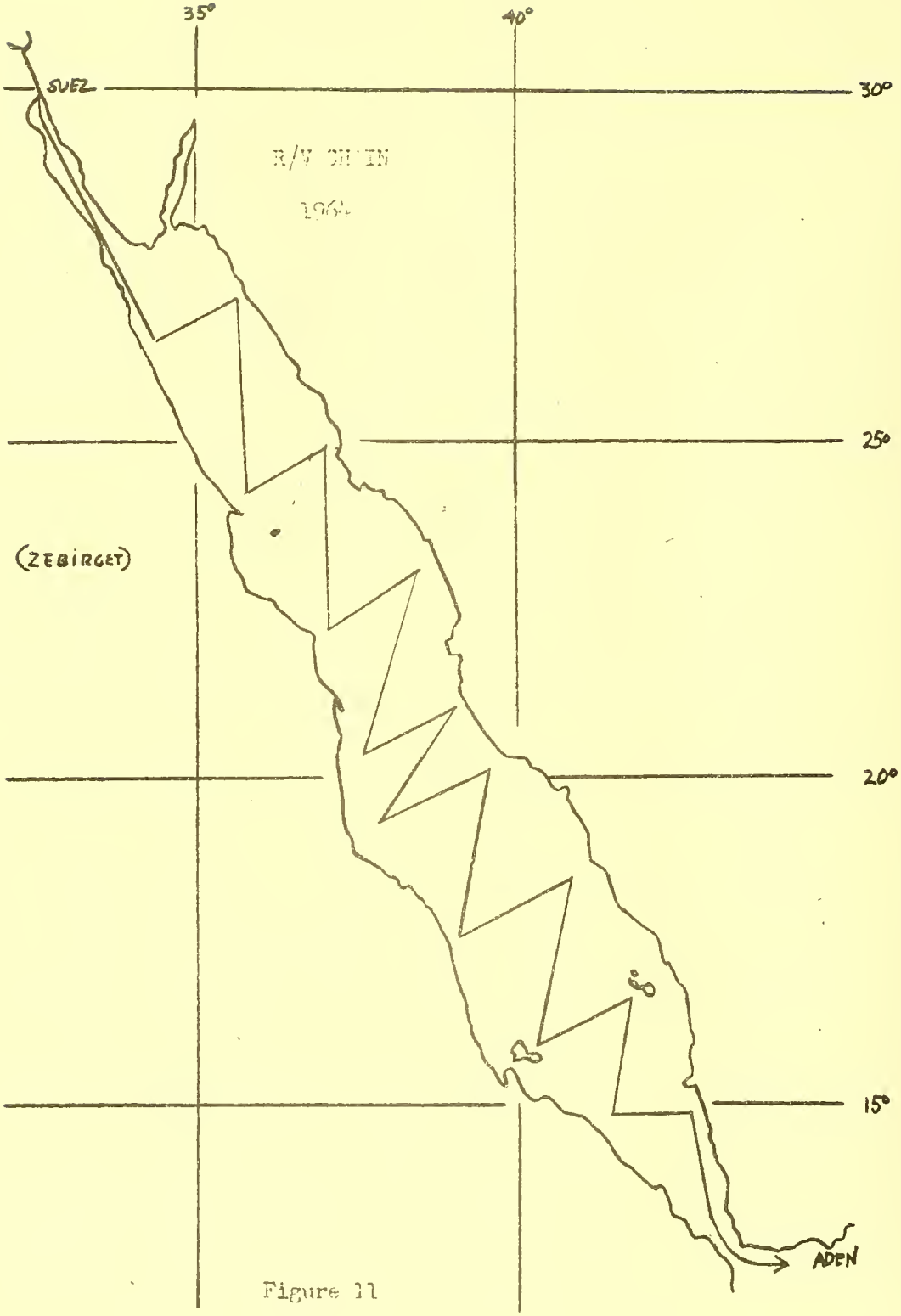


Figure 11

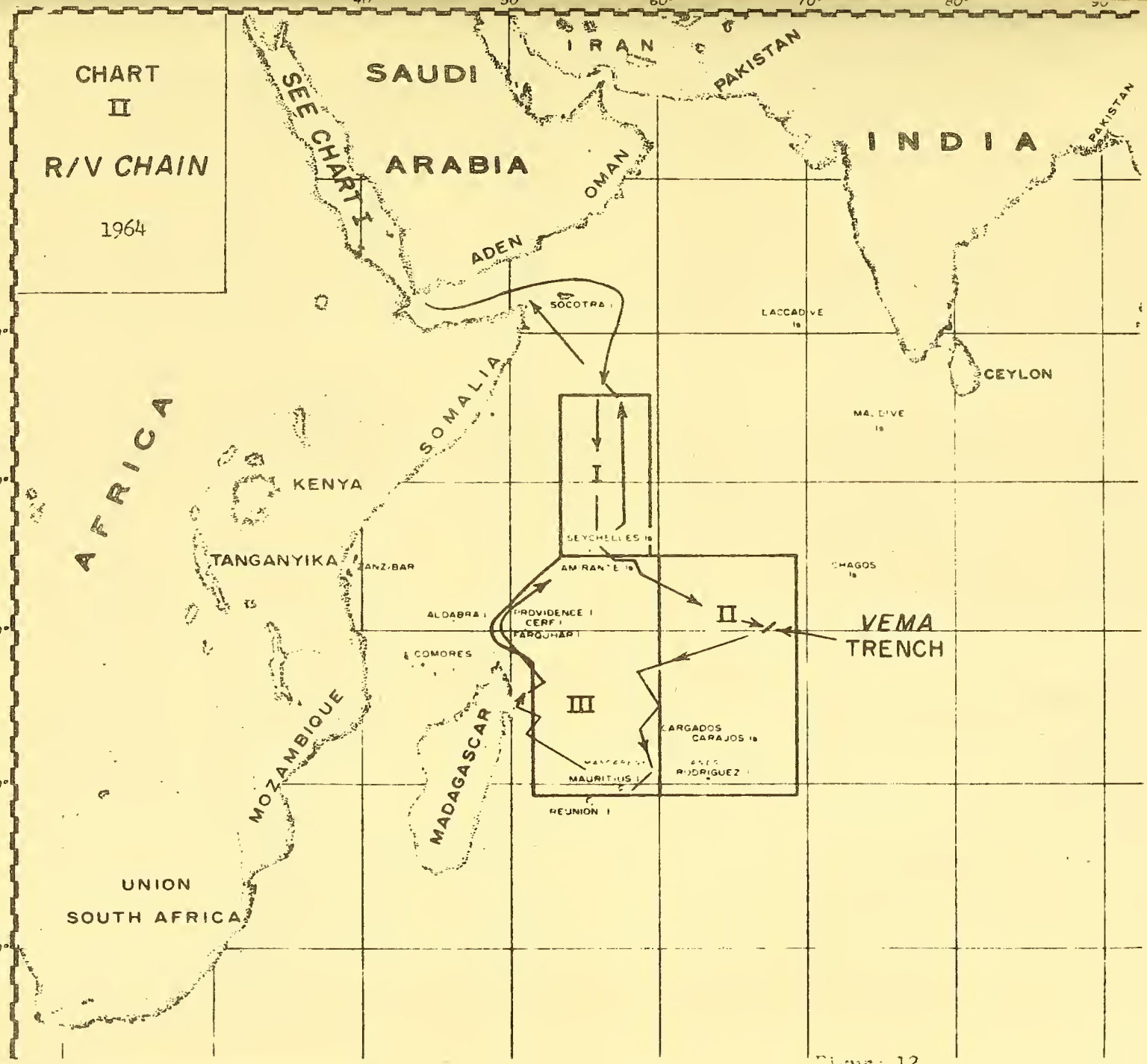


CHART
II
R/V CHAIN
1964
SEE CHART I
SAUDI
ARABIA
IRAN
PAKISTAN
INDIA
PAKISTAN
OMAN
ADEN
SOCOTRA I
LACCADIVE Is
CEYLON
MALDIVE Is
SOMALIA
AFRICA
KENYA
TANGANYIKA
ZANZIBAR
SEYCHELLES Is
AMIRANTE Is
CHAGOS Is
ALDABRA I
PROVIDENCE I
CERF I
FAROJHAR I
COMORES
I
II
III
VEMA
TRENCH
MOZAMBIQUE
MADAGASCAR
CARGADOS
CARAJOS Is
RODRIGUEZ I
MAURITIUS I
REUNION I
UNION
SOUTH AFRICA
40°
50°
60°
70°
80°
90
10°
0°
10°
20°
30°

Figure 12

Area I is a portion of the Somali Abyssal Plain. Results of the VEMA show a thick layer or series of layers of sediments above a deep reflecting horizon, with some peaks thrusting through the sediment cover. The CHAIN will dredge one or two of these peaks for rock samples and core sediments. Scarps and outcrops will be dredged. Bottom photographs will be taken, and oblique reflection profiles will be made using acoustic telemetering buoys. Heat flow measurements will be made between Aden and the Seychelles.

In Area II, the detailed study of the Seychelles-Mauritius Ridge will be continued. The Vema Trench, the deepest spot in the Indian Ocean (3,501 fathoms), will also be studied in detail. In Area III the relationship between Madagascar and the Seychelles-Mauritius Ridge will be investigated, alternating broad-scale underway survey work with more closely spaced survey tracks and with core samples and heat flow measurements. A small trench to the southwest of the Almirante Islands is of particular interest in this region and will be investigated with dredging and photography.

Subsequent Woods Hole cruises are planned as follows:

1964	Sept-March 1965	CHAIN	Geophysics and Submarine Geology, Cape Agulhas to Laccadives, Chagos to India, India to Suez.
1965	Feb-July	ATLANTIS II	Physical and Chemical Studies in Red Sea Agulhas Currents.

The programs indicated for the CHAIN and ATLANTIS II respectively are the primary ones. The CHAIN cruises will also include physical and chemical oceanography and the ATLANTIS II cruises geophysics and submarine geology. Key scientists involved in the above program are Earl E. Hays, J. B. Hersey, C. O'D. Iselin and A. R. Miller.

Also based at the Woods Hole Oceanographic Institution is the U. S. Program in Biology under the direction of Dr. John H. Ryther, assisted by Dr. Edward Chin. The Program in Biology has compiled and distributed more than 1,500 copies of A Partial Bibliography of the Indian Ocean (Yentsch et al., 1962), and has supported the preparation of Preliminary Field Guides to the Birds and Scombridae of the Indian Ocean (Watson, Zusi, and Storer, 1963, Collette and Gibbs, 1963). These guides prepared under the sponsorship of the U. S. National Museum are being distributed to ships and interested persons participating in the International Indian Ocean Expedition.

The major effort of the U. S. Program in Biology is based on a series of nine cruises of a biological oceanographic research vessel scheduled to take place during 1963 and 1964. In addition, support is also being provided for scientists to participate on an auxiliary vessel, at two existing shore

laboratories, and as independent investigators in certain areas and island groups of the Indian Ocean.

1. The Biological Oceanographic Ship Cruises

The R/V ANTON BRUUN has been designated as the main biological research vessel. Responsibility for operation of the vessel has been contracted to Alpine Geophysical Associates, Inc. of Norwood, New Jersey. During her period of participation in the Expedition, the ANTON BRUUN will be based at Bombay. Also stationed at Bombay as Scientific Liaison Officer is Dr. T. S. Satyanarayana Rao, on leave from Andhra University in India.

On each of the nine cruises planned, stations will be occupied at intervals of 2° to 5° latitude on the meridional sections and more frequently on the coastal cruises. The basic program at each station will consist of the following:

a. Hydrographic cast to 1,000 meters for temperature, salinity, dissolved oxygen, phosphate, nitrate, nitrite, silicate, ammonia.

b. Van Dorn bottle cast to depths of penetration of 100, 50, 25, 10, and 1% of incident light for pigment analysis and for 24-hour simulated <u>in situ</u> and 4-hour incubator C^{14} uptake experiments.

c. Submarine light penetration at all daylight stations.

d. Vertical plankton haul from 200 meters with standard IOE net (mesh aperture = 0.330 mm) for deposition in International Taxonomic Center at Cochin, India.

e. Vertical micro-plankton haul from 200 meters with No. 25 mesh net.

f. Oblique plankton tow with Be′ sampler (mesh aperture - 0.33 mm) from 2,000 meters or greatest depth possible in shallow water.

g. Bathythermograph observation.

Additional work to be undertaken on each cruise will vary depending on each cruise. Intensive sampling will be done with different types of gear, as shown below in the cruise schedule established for the ANTON BRUUN.

<u>ANTON BRUUN Cruise I (Figure 13)</u>

Arrived		Sailed		
	1963			
3 Mar		12 Mar	Bombay	Gulf of Mexico

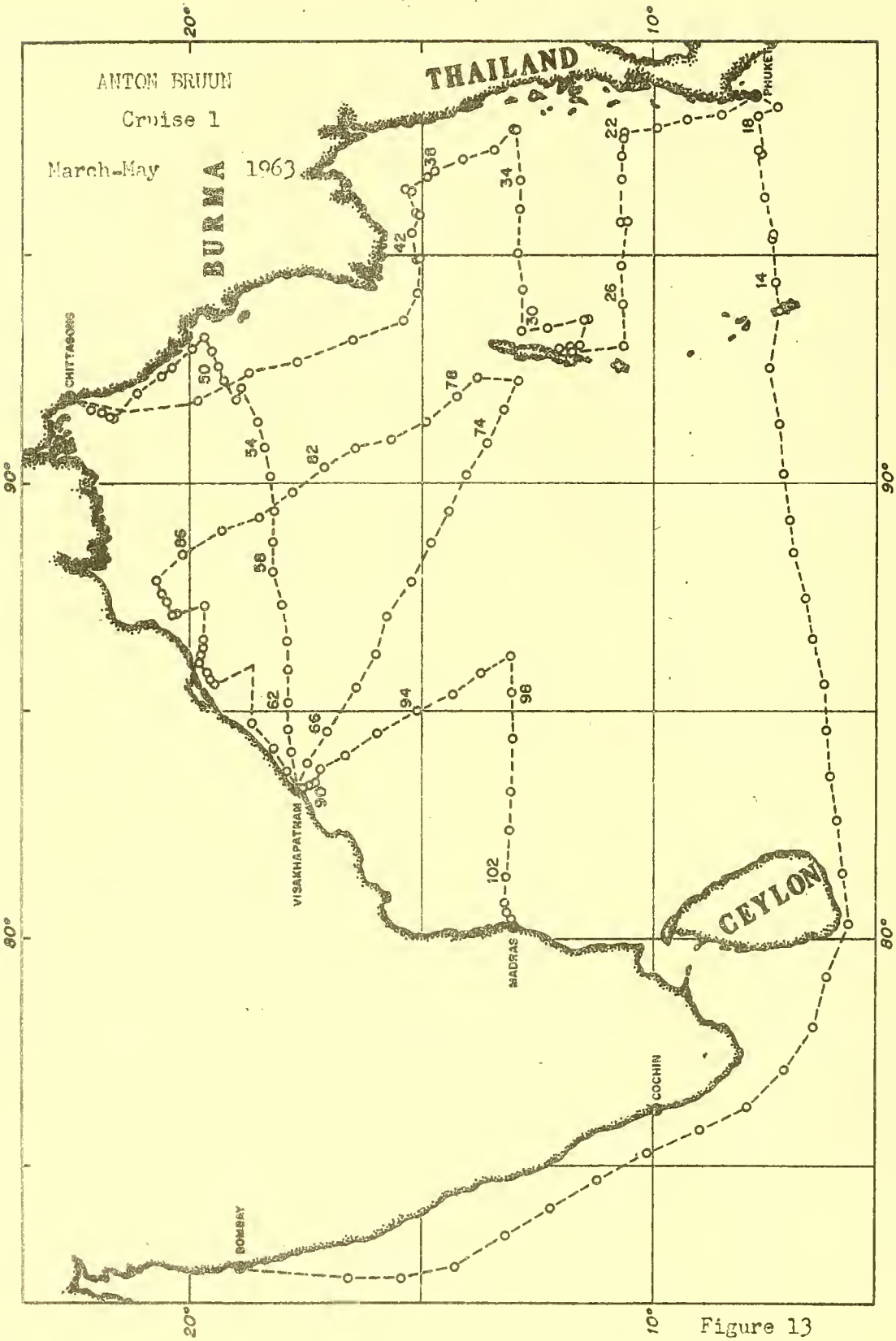
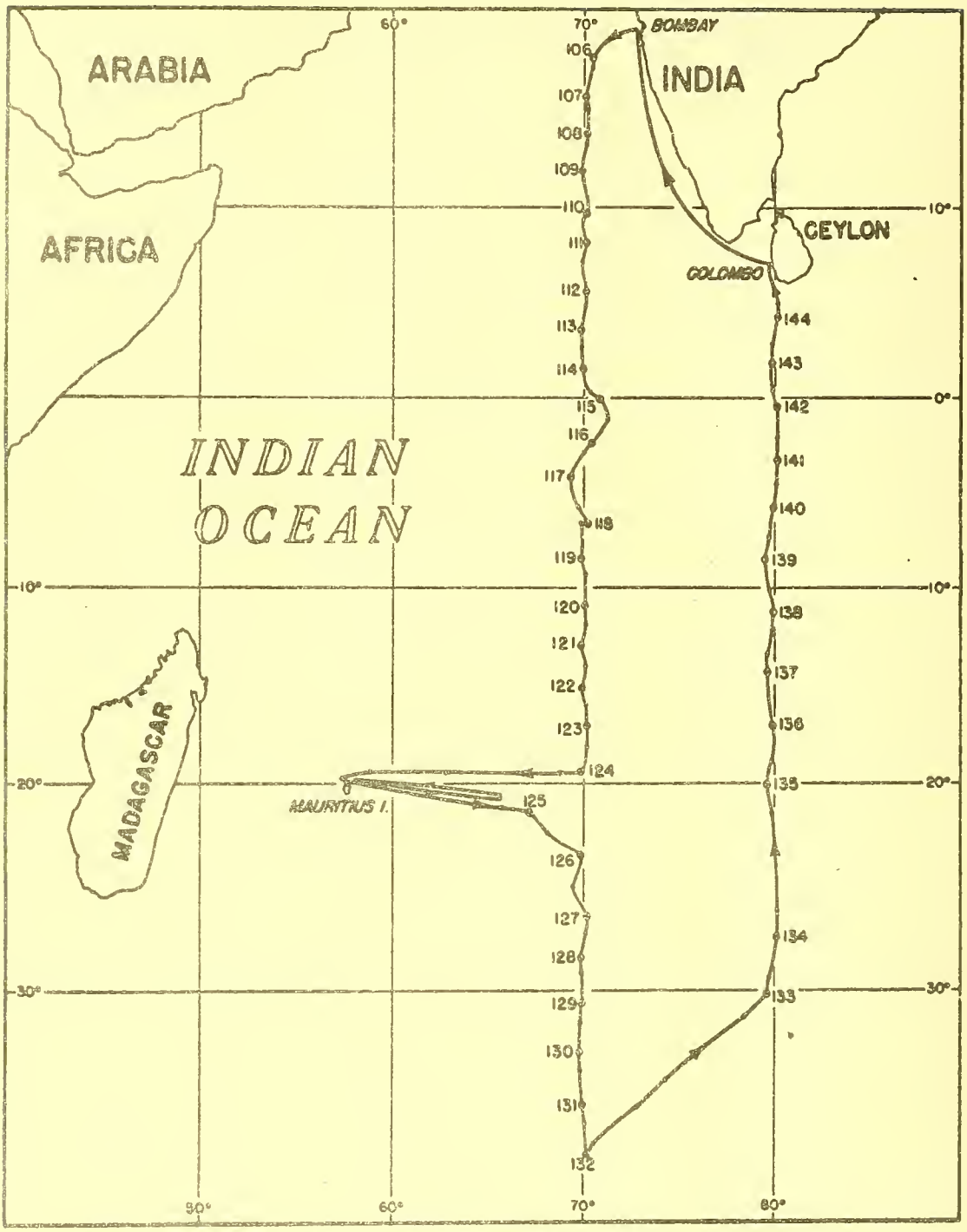

ANTON BRUUN
Cruise 1
March-May 1963
THAILAND
BURMA
CEYLON
PHUKET
CHITTAGONG
VISAKHAPATNAM
MADRAS
COCHIN
BOMBAY
20°
10°
90°
80°

Figure 13

ANTON BRUUN (Cont'd)

Arrived	Sailed		
22 Mar	23 Mar	Puket, Thailand	shrimp trawl,
3 Apr	4 Apr	Chittagong	occasionally
11 Apr	14 Apr	Visakhapatnam	dredges.
10 May	-	Bombay	
		CRUISE 2 (Figure 14)	
-	22 May	Bombay	Japanese long-line
14 Jun	18 Jun	Port Louis, Mau.	fishing gear
22 Jun	22 Jun	Port Louis, Mau.	
18 Jul	19 Jul	Colombo, Ceylon	
23 Jul	-	Bombay	
		CRUISE 3 (Figure 15)	
-	18 Aug	Bombay	Isaacs-Kidd
29 Aug	3 Sep	Port Louis	midwater trawl
20 Sep	-	Port Louis	
		CRUISE 4 (Figure 16)	
-	25 Sep	Port Louis	Gulf of Mexico
1 Oct	3 Oct	Victoria, Seychelles	shrimp trawl,
11 Oct	15 Oct	Aden	occasionally
24 Oct	28 Oct	Karachi	dredges.
10 Dec	-	Karachi	
		CRUISE 5 (Figure 17)	
1964			
-	26 Jan	Bombay	Japanese long-line
11 Feb	15 Feb	Victoria, Seychelles	fishing gear
22 Feb	2 Mar	Port Louis	
23 Mar	26 Mar	Cochin	
28 Mar	-	Bombay	
		CRUISE 6 (Figure 18)	
-	9 Apr	Bombay	Isaacs-Kidd
30 Apr	4 May	Port Louis	midwater trawl
1 Jun	-	Durban	



Track Chart of the ANTON BRUUN, Cruise 2, May 22 - July 23, 1963

Figure 14

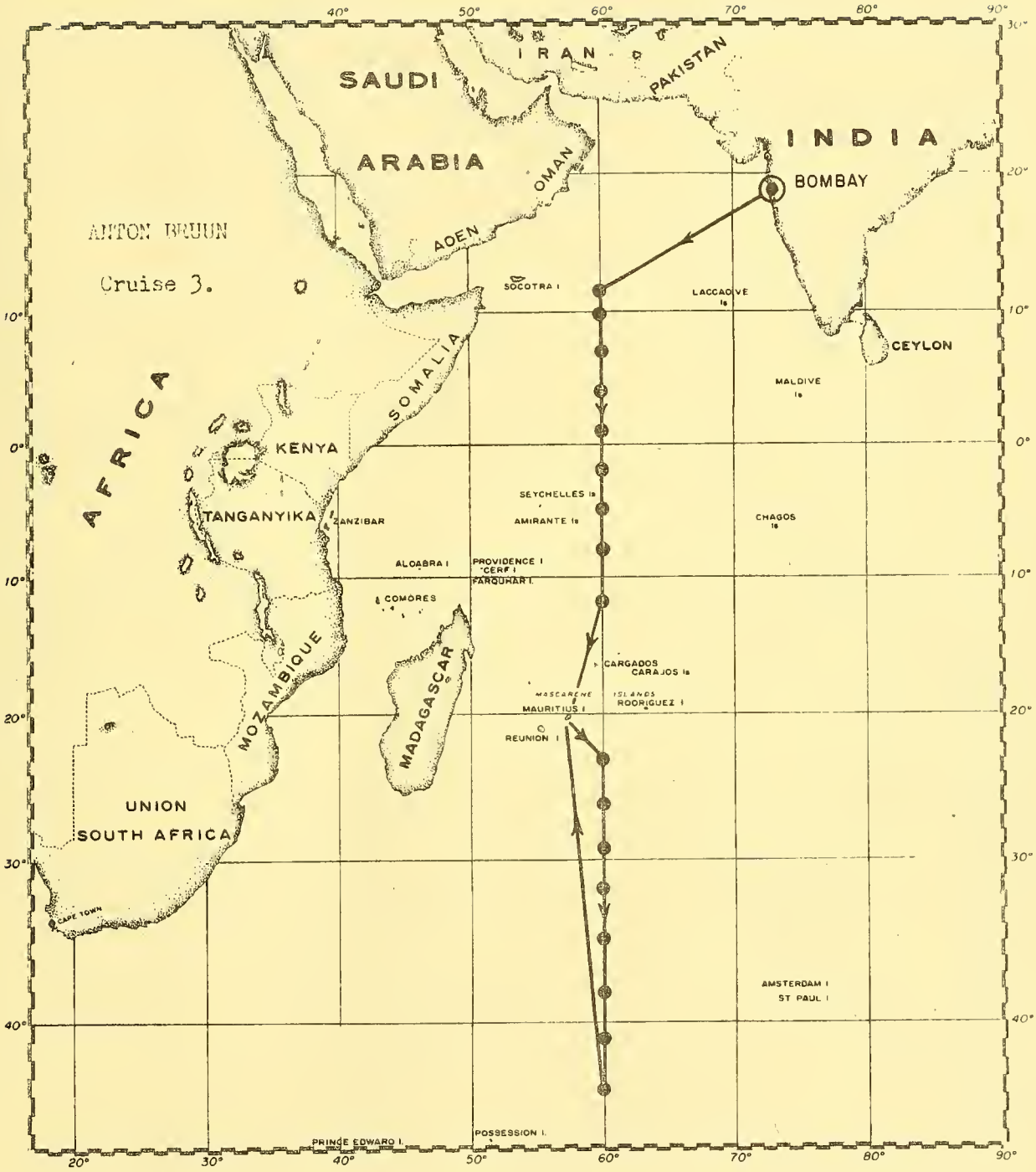

ANTON BRUUN
Cruise 3.
SAUDI
ARABIA
IRAN
PAKISTAN
INDIA
BOMBAY
OMAN
ADEN
SOCOTRA I
LACCADIVE Is
CEYLON
MALDIVE Is
SOMALIA
AFRICA
KENYA
TANGANYIKA
ZANZIBAR
SEYCHELLES Is
AMIRANTE Is
CHAGOS Is
ALDABRA I
PROVIDENCE I
CERF I
FARQUHAR I.
COMORES
MOZAMBIQUE
MADAGASCAR
CARGADOS CARAJOS Is
MASCARENE ISLANDS
MAURITIUS I
ROORIGUEZ I
REUNION I
UNION
SOUTH AFRICA
CAPE TOWN
AMSTERDAM I
ST PAUL I
PRINCE EDWARD I.
POSSESSION I.
20°
30°
40°
50°
60°
70°
80°
90°
10°
0°

FIGURE 15

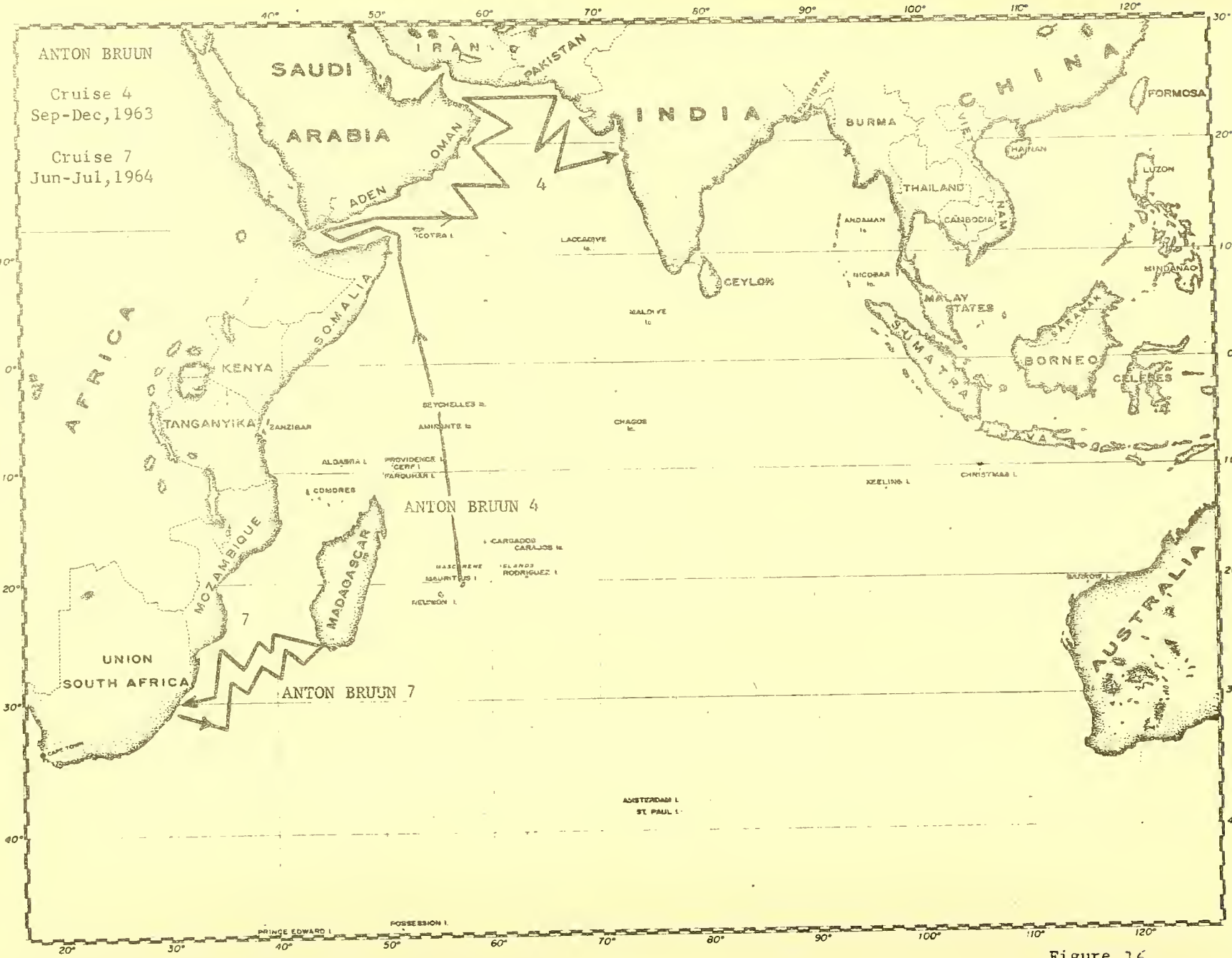

ANTON BRUUN
Cruise 4
Sep-Dec, 1963
Cruise 7
Jun-Jul, 1964
SAUDI
ARABIA
IRAN
PAKISTAN
INDIA
CHINA
BURMA
THAILAND
CAMBODIA
FORMOSA
HAINAN
LUZON
MINDANAO
OMAN
ADEN
SOMALIA
AFRICA
KENYA
TANGANYIKA
ZANZIBAR
MOZAMBIQUE
MADAGASCAR
UNION
SOUTH AFRICA
CEYLON
MALAY
STATES
SUMATRA
BORNEO
CELEBES
JAVA
AUSTRALIA
COMORES
ANTON BRUUN 4
ANTON BRUUN 7
4
7

Figure 16

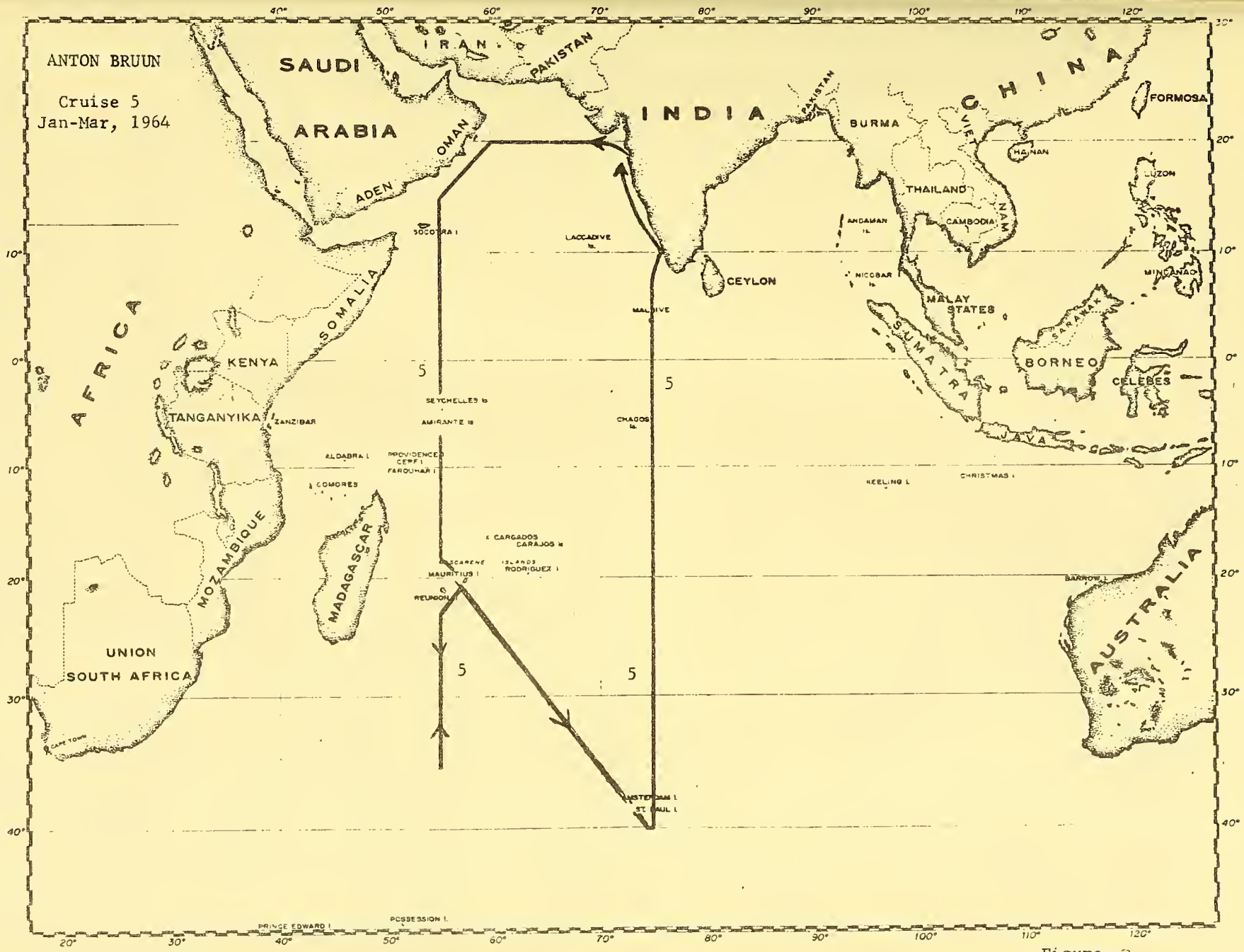

ANTON BRUUN
Cruise 5
Jan-Mar, 1964
SAUDI
ARABIA
IRAN
PAKISTAN
INDIA
CHINA
FORMOSA
BURMA
VIET
NAM
HAINAN
LUZON
THAILAND
CAMBODIA
ANDAMAN
NICOBAR
MINDANAO
MALAY
STATES
SUMATRA
BORNEO
SARAWAK
CELEBES
JAVA
CEYLON
LACCADIVE
MALDIVE
CHAGOS
SOCOTRA I
ADEN
OMAN
SOMALIA
AFRICA
KENYA
TANGANYIKA
ZANZIBAR
SEYCHELLES
AMIRANTE
ALDABRA I
PROVIDENCE
CERF I
FAROUHAR I
COMOROS
MADAGASCAR
MOZAMBIQUE
UNION
SOUTH AFRICA
CARGADOS
CARAJOS
MAURITIUS I
RODRIGUEZ I
REUNION
KEELING I
CHRISTMAS I
AUSTRALIA
BARROW I
AMSTERDAM I
ST. PAUL I
PRINCE EDWARD I
POSSESSION I.
5
5
5
5

Figure 17

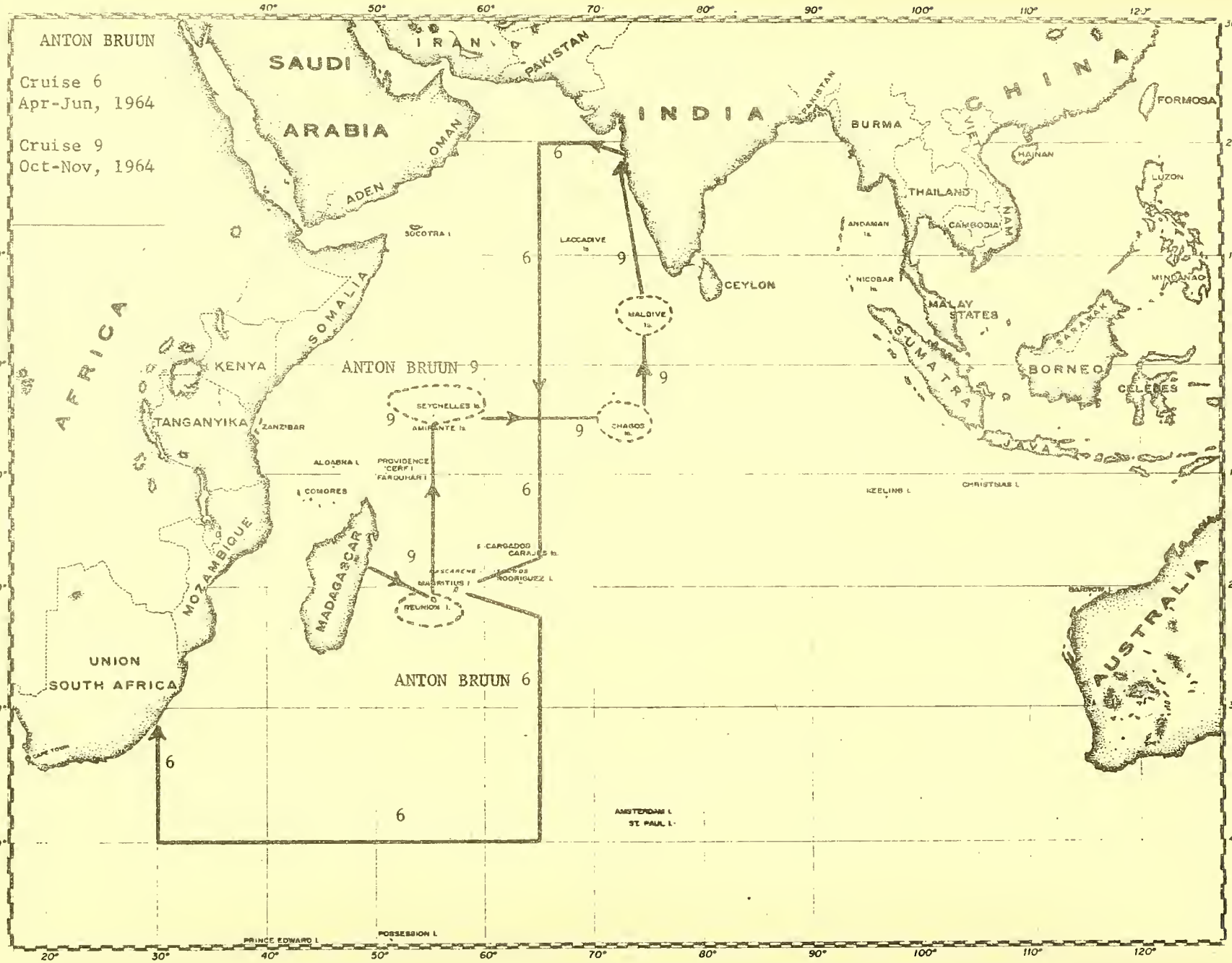

ANTON BRUUN
Cruise 6
Apr-Jun, 1964
Cruise 9
Oct-Nov, 1964
SAUDI
ARABIA
IRAN
PAKISTAN
INDIA
CHINA
FORMOSA
BURMA
THAILAND
CAMBODIA
VIET NAM
HAINAN
LUZON
MINDANAO
ADEN
OMAN
SOCOTRA I
LACCADIVE
MALDIVE
CEYLON
ANDAMAN
NICOBAR
MALAY STATES
SUMATRA
BORNEO
SARAWAK
CELEBES
JAVA
AFRICA
SOMALIA
KENYA
TANGANYIKA
ZANZIBAR
MOZAMBIQUE
UNION
SOUTH AFRICA
MADAGASCAR
ANTON BRUUN 9
SEYCHELLES
AMIRANTE
CHAGOS
ALDABRA I
PROVIDENCE
CERF I
FARQUHAR I
COMORES
CARGADOS CARAJOS
MASCARENE
MAURITIUS I
RODRIGUEZ I
REUNION I.
ANTON BRUUN 6
KEELING I
CHRISTMAS I
BARROW I
AUSTRALIA
AMSTERDAM I
ST. PAUL I.
PRINCE EDWARD I
POSSESSION I
CAPE TOWN

Figure 18

ANTON BRUUN (Cont'd)

CRUISE 7 (Figure 16)

Arrived	Sailed		
-	12 Jun	Durban	Menzies trawl,
23 Jun	27 Jun	Lourenco Marques	Campbell grab,
9 Jul	13 Jul	Tulear, Madagascar	piston corer
26 Jul	-	Durban	

CRUISE 8 (Figure 19)

-	6 Aug	Durban	Gulf of Mexico
19 Aug	22 Aug	Beira	shrimp trawl,
27 Aug	30 Aug	Mozambique	dredges.
9 Sep	13 Sep	Zanzibar	
25 Sep	-	Tamatave	

CRUISE 9 (Figure 18)

-	3 Oct	Tamatave	Gulf of Mexico
5 Oct	12 Oct	Port des Galetes (Reunion)	shrimp trawl, midwater trawl.

To permit the greatest continuity and degree of consistency in the results, there is a permanent scientific staff of eight on board the ANTON BRUUN which has responsibility for making the hydrographic casts, bathythermograph observations, plankton tows, physical and chemical determinations (temperature, salinity, light penetration, dissolved oxygen, phosphate, nitrate, nitrite, silicate, ammonia), and productivity measurements. The permanent scientific staff, composed mainly of graduate students in biology or oceanography, has received a special three-month course in oceanographic methods and theory at the Bermuda Biological Station from Dr. David Menzel, Director of the Training Program, Dr. Francis Richards (University of Washington), Dr. Maxwell Doty (University of Hawaii), Dr. Harold Humm (Duke University), Dr. Donald Squires (U. S. National Museum), Messrs, A. R. Miller and M. Bartlett (Woods Hole Oceanographic Institution), Dr. Alan W. H. Bé (Lamont Geological Observatory), and Messrs. Henry White and David Wingate (Bermuda).

SCIENTIFIC PERSONNEL SCHEDULED TO WORK ABOARD R/V ANTON BRUUN

CRUISE 1	CRUISE 2	CRUISE 3
R. T. Abbott	Isamu Asari	Alan W.H. Bé
S. P. Anand (India)	Andrew Bakun	T. Chen
K. Balasubrahmanyan (India)	Peter Connors	G. L. Clarke
P. W. Baokar (India)	Don F. Fenner	Peter Connors
M. Bhovichitra	John R. Hall	Alfred Ebeling

ANTON BRUUN
Cruise 2
May-Jul, 1963
Cruise 8
Aug-Sep, 1964
ANTON BRUUN 8
SAUDI ARABIA
IRAN
PAKISTAN
INDIA
CHINA
FORMOSA
BURMA
VIET NAM
THAILAND
CAMBODIA
LUZON
MINDANAO
ADEN
OMAN
SOCOTRA I.
LACCADIVE Is.
CEYLON
ANDAMAN Is.
NICOBAR Is.
MALAY STATES
SUMATRA
BORNEO
SARAWAK
CELEBES
JAVA
MALDIVE Is.
SOMALIA
AFRICA
KENYA
TANGANYIKA
ZANZIBAR
SEYCHELLES Is.
AMIRANTE Is.
CHAGOS Is.
ALDABRA I.
PROVIDENCE I.
CERF I.
FARQUHAR I.
COMORES
KEELING I.
CHRISTMAS I.
MOZAMBIQUE
MADAGASCAR
CARGADOS CARAJOS Is.
MASCARENE ISLANDS
RODRIGUEZ I.
MAURITIUS I.
REUNION I.
UNION SOUTH AFRICA
CAPE TOWN
AUSTRALIA
AMSTERDAM I.
ST. PAUL I.
PRINCE EDWARD I.
POSSESSION I.

Figure 19

SCIENTIFIC PERSONNEL (Cont'd)

CRUISE 1

Edward Brinton
P. Chandramohan (India)
P. K. Das (India)
O. M. Gupta (India)
Thomas S. Hida
Alan Kamb
R. M. Kidwai (India)
Eugene C. LaFond
Katherine LaFond
Agdar K. Larssen
K. V. Nair (India)
Richard Norris
N. K. Panikkar (Inida)
Alonzo T. Pruter
C. H. Rao (India)
C. P. Rao (India)
G. R. Rao (India)
V. C. Rao (India)
Mr. Ramireddi (India)
M. Sakthival (India)
V. N. Sankaranarayanan (India)
T. S. Satyanarayana Rao (India)
James S. Sterling
G. Subbaraju (India)
Thumnoon Sunpanish (Thailand)
William R. Taylor
James Tyler
R. V. Unnithan (India)
V. V. R. Varadachari (India)
S. Varma (India)
R. Varadarajulu (India)
A. B. Wagh (India)

CRUISE 2

Joseph P. Hennessy
Everet C. Jones
Mark M. Jones
Mahlon G. Kelly
Charles P. Lee
Alan Lewis
George K. Lindsey
Sanson McDowall, Jr.
Sidney L. McGuire
Richard E. Norris
Mohadev Parab (India)
Alan K. Pease
Bruce A. Rogers
K. N. Sankolli (India)
Richard S. Shomura
Richard Y. Suzuki
Sidney J. Townsley
Shigeru Yano

CRUISE 3

Jack Fell
Robert Gibbs, Jr.
Sidney Townsley
Shigeru Yano

CRUISE 4

R. J. Barsdate
L. S. Cieresko
R. C. Dugdale
R. Foster
F. Fraga (Spain)
T. S. Hida
W. J. Hargis

CRUISE 5

M. B. Allen
S. Kite
E. J. Kuenzler
M. M. Mullin
R. Norris
R. Shomura
M. Vannucci (Brazil)

CRUISE 6

R. H. Backus
D. M. Cohen
G. D. Grice
G. W. Mead
R. Norris
R. L. Haedrich

CRUISE 4 (Cont'd)

J. K. Kunnenkeri (India)
E. A. Lachner
R. Norris
A. T. Pruter
M. Watson
S. Watson
L. P. Woods

CRUISE 7

O. L. Bandy
K. J. Boss
M. R. Carriker
E. Cutler
B. C. Heezen
R. J. Menzies
R. Norris
V. Orr
D. F. Squires
W. Wieser (Austria)

CRUISE 8

K. J. Boss
B. B. Collette
N. Della Croce (Italy)
R. Foster
S. Frontier (France)
R. U. Gooding (Gr. Britain)
R. M. Johnson
R. Norris
F. D. Por (Israel)
S. Springer
M. L. Wass

CRUISE 9

H. Brattstrom (Sweden)
F. G. Carey
R. U. Gooding
E. Kirsteuer (Austria)
R. Norris
E. L. Pierce
R. H. Rosenblatt
R. W. Storer
V. Springer
J. M. Teal
M. Watson
S. Watson

The U. S. Bureau of Commercial Fisheries is cooperating with the Program in Biology and will participate in Cruises 1, 2, 4, and 5 of the ANTON BRUUN. Funds from the Program in the amount of nearly $57,000, were reallocated to the Bureau to supplement the $70,000 budgeted by the Bureau for its first year of participation (Cruises 1 and 2).

The research program of the Bureau will include a program of longline fishing on Cruises 2 and 5 to sample the tunas, marlins, sharks, and other apex predators. The Bureau is especially interested in the distribution and abundance of adult tunas in relation to the circulation during the two monsoon seasons; the relation of the apex predators to the food-chain, standing crops, and productivity; and the identification of subpopulations of tunas and other apex predators by means of serological techniques. Catches will be weighed and measured, recordings will be made of the sex and maturation of the gonads, collections of stomach contents, ovaries, and blood samples will be obtained, and certain specimens will be retained for taxonomic work.

The Bureau will also conduct a program of bottom trawling on Cruises 1 and 4 to study the distribution and relative abundance of demersal species in relation to the topography and nature of the bottom, with emphasis on species

of potential commercial importance. In addition, Bureau scientists will be studying tuna larvae, juvenile tuna, and certain copepod species.

2. Auxiliary Ship Cruises

Due to the interest shown in carrying on physiological studies and making collections and observations in and around the island groups and in the shallow water areas of the Indian Ocean, arrangements have been made through Dr. Rolf Bolin of Stanford University to have TE VEGA operate in the Indian Ocean for approximately one year. TE VEGA, a 135-ft. two-masted schooner will make three cruises scheduled as follows:

Cruise A.	October-December, 1963	Singapore, Colombo, Ceylon: Stops along island groups off the Malay Peninsula and/or those off Sumatra.
Cruise B	March-May, 1964	Colombo - Mauritius. Stops along the Maldives, Chagos Island, Cochin.
Cruise C	June-September, 1964	Mauritius - Zanzibar. Stops along the Comoro Islands and the northwestern coast of Madagascar.

Since TE VEGA is primarily a teaching facility, only six participants in the U. S. program in Biology can be accommodated at a time on each of the three cruises. The ship will be equipped with small boats, limited laboratory space, a darkroom, SCUBA, a winch for dredging and trawling at depths of 3,000 fathoms, and general collecting gear.

SCIENTIFIC PERSONNEL SCHEDULED TO WORK ABOARD R/V TE VEGA

CRUISE A	CRUISE B	CRUISE C
L. H. Colinvaus (Canada)	E. Y. Dawson	I. Boetius (Denmark)
F. Gill	J. S. Garth	J. Boetius (Denmark)
A. J. Kohn	L. S. Kornicker	I. J. Deyrup
R. H. Rosenblatt	R. Robertson (Gr. Britain)	M. Gordon
J. Rosewater	L. P. Woods	J. Mead
K. Rutzler (Austria)	F. C. Ziesenhenne	W. H. Sawyer
		K. Schmidt-Nielsen
		P. F. Scholander

SCIENTIFIC PERSONNEL SCHEDULED AT STATION OCEANOGRAPHIQUE, NOSSI BE, MADAGASCAR

A. W. H. Bé
J. S. Bradshaw
R. F. Cressey
E. B. Cutler
R. P. Higgins
A. G. Humes
A. J. Kohn
R. F. Maddocks
J. McLaughlin
R. Riedl (Austria)
H. D. Russell
H. L. Sanders
P. C. Silva
D. H. Steele (Canada)
W. Wieser (Austria)

SCIENTIFIC PERSONNEL SCHEDULED AT THE CENTRAL MARINE FISHERIES RESEARCH INSTITUTE AT MANDAPAM CAMP, INDIA

M. B. Allen
K. M. S. Aziz (Pakistan)
J. E. Bardach
E. Brinton
C. E. Cutress
E. Y. Dawson
G. M. Friedman
J. S. Garth
M. K. Hecht
R. P. Higgins
G. Jagersten (Sweden)
J. S. Karling
E. J. Kuenzler
J. McLaughlin
R. Robertson (Gr. Britain)
I. Rubinoff
H. Sanders
J. C. Thompson, Jr.
M. Vannucci (Brazil)
L. P. Woods
W. Yaphe (Canada)
F. C. Ziesenhenne

3. Shore Laboratories

For those scientists interested in carrying on studies at shore laboratories in the Indian Ocean area, arrangements have been made to accommodate participants at the Centre d'Oceanographie et des Peches at Nossi Bé, Madagascar, and at the headquarters laboratory of the Central Marine Fisheries Research Institute at Mandapam Camp, India.

Dr. Arthur G. Humes, Professor of Biology at Boston University, has been designated as Chief Scientist and Liaison Officer for the U. S. participants at the Centre d'Oceanographie et des Peches.

A vehicle, inflatable Zodiac boat, outboard motor, microscopes, and other items have been provided at each of the two shore laboratories to supplement the equipment and supplies that are being made available to participants in the U. S. program.

4. Independent Studies

Several groups of independent investigators interested in carrying on intensive studies in certain areas of the Indian Ocean have been supported by the Program in Biology, and several additional groups are scheduled for support. These studies include:

a. Locality: Southern Red Sea, off island of Entedebir, in the Dahlac Archipelago off the Ethiopian coast.

	Time:	March-April, 1962
	Participants:	Drs. Eugenie Clark, George Papenfuss, Thomas Goreau, and Stephen Wainwright.
	Fields of Interest:	Sharks, fishes, marine algae, corals, reef ecology.
b.	Locality:	Southwest Australia, Mauritius, Madagascar
	Time:	August-September 1962
	Participants:	Dr. Robert Seagel
	Fields of Interest:	Marine algae.
c.	Locality:	East African coast and Aden
	Time:	September-December, 1962
	Participants:	Drs. Robert Seagel and George Papenfuss, joined in Kenya and Tanganyika by Dr. George Lawson.
	Field of Interest:	Marine algae.
d.	Locality:	Cocos-Keeling
	Time:	January-February, 1963
	Participants:	Miss Virginia Orr and Mrs. E. R. Ostheimer
	Field of Interest:	Mollusks.
e.	Locality:	East coast of India
	Time:	January-February, 1963
	Participants:	Mr. C. M. Cutress
	Field of Interest:	Sea anemones.
f.	Locality:	West coast of India
	Time:	January-February, 1963
	Participants:	Mr. K. M. Aziz
	Field of Interest:	Marine Algae.

g. Locality: Seychelles

Time: January-February, 1964

Participants: Drs. James Bohlke, John Randall, and three others

Field of Interest: Marine fishes

h. Locality: Seychelles

Time: December, 1963-March, 1964

Participants: Messrs. Richard W. Foster and Samuel Fuller

Field of Interest: Mollusks

i. Locality: West coast of India

Time: January-February, 1964

Participants: Mr. John Reintjes

Field of Interest: Clupeid fishes

j. Locality: Comoro Islands

Time: October-December, 1964

Participants: Mr. Richard W. Foster and Dr. Ruth Turner

Field of Interest: Mollusks

Woods Hole Oceanographic Institution is also operating the C54Q aircraft 50874 over the Indian Ocean in 1963 and 1964. Under Professor Andrew F. Bunker, scientist in charge, with William Ewing as pilot, a crew of 3, Richard Leahy as geochemist, Claud Ronne as photographer, and 3 more in the scientific party, the aircraft will undertake observations of dropsonde humidity and temperature, wind, solar and albedo radiation fluxes, turbulent transport of heat, water vapor and momentum, nuclei counts, cloud distribution, and radar observations of precipitation areas.

The following was the itinerary for 1963:

Arrive	Leave
May 20 Lages, Agnes	May 21
May 21 Chatèauroux	May 22
May 22 Athens	May 23

Itinerary (Cont'd)

Arrive	Leave	
May 23 Tehran	May 24	
May 24 Karachi	May 25	
May 25 Bombay	June 3	May 29-June 1, local flights parallel West Coast India
June 3 Madras	June 4	
June 4 Bangkok	June 7	June 5-6, local flights Bay of Bengal
June 7 Madras	June 8	
June 8 Bombay	June 11	
June 11 Gan	June 12	
June 12 Keeling I	June 14	Local flights June 13
June 14 Gan	June 15	
June 15 Bombay	July 1	
July 1 Gan	July 2	
July 2 Keeling I	July 4	Local flights July 3
July 4 Gan	July 5	
July 5 Bombay	July 11	Local flights, parallel West Coast July 8 and 9
July 11 Tehran	July 12	

The Woods Hole C54 returned to Bombay on February 9, 1964 and is still in the Indian Ocean area where it is collecting atmospheric data for the University of Washington and the University of Hawaii in addition to the Woods Hole program.

UNIVERSITY OF WASHINGTON

The University of Washington operated the instrumented buoy MENTOR in the North Arabian Sea from January through March, 1964.

A vertical flux measurement program under the direction of Dr. Robert G. Fleagle is designed to measure fluctuations in velocity components, temperature, and humidity from which the evaporation, heat transfer, and stress may be directly computed. Profile observations, together with the fluctuation measurements, permit calculation of exchange coefficients. Data were telemetered by cable to a tending vessel and recorded on magnetic tape. It is hoped to achieve resolution in water vapor flux (expressed as the equivalent flux of "latent heat") better than 0.1 cal $cm^{-2}min^{-1}$ with corresponding resolution in stress and heat flux.

The buoy program is coordinated with the aircraft observation program operated by the U. S. Weather Bureau and Woods Hole Oceanographic Institution. Aircraft flew a closed path equivalent in area to a square about 500 km on a side. From observations of wind velocity, humidity, and temperature the net horizontal outflow or inflow of water vapor, heat, and momentum will be

calculated. Continuity equations then yield the mean rates of evaporation, heat flux, and the stress over the area. These results will be compared with the corresponding values calculated from fluctuations and profiles. To achieve resolution of 0.1 cal $cm^{-2}min^{-1}$ in water vapor flux it will be necessary to detect humidity differences of about 0.3 g kg^{-1} on opposite sides of the enclosed region.

Dr. Franklin Badgley and four University of Washington scientists unloaded and assembled MENTOR in Bombay in late January 1964. On February 11, the chartered Dutch tug OCEAN towed the buoy to a spot 65 km west of the city. The intensified aircraft-buoy atmospheric-sea interface program was completed by mid-March 1964.

U. S. COAST GUARD

During May 1961, the U. S. Coast Guard Icebreaker EAST WIND, returning from a trip to the Antarctic with oceanographic observers from the Hydrographic Office aboard, occupied a line of hydrographic stations from Fremantle west to 78°E, then to 4°N (Tressler, 1963). Her track is shown in Figure 20.

U. S. NAVY

Survey vessels of the U. S. Navy have planned and occupied hydrographic stations in the Persian Gulf and Andaman Sea, as shown in Figure 20. Swinnerton and Sullivan (1962) have reported some of the results.

The research vessels CHAIN of Woods Hole Oceanographic Institution, ARGO of Scripps Institution of Oceanography, and CONRAD of Lamont Geological Observatory are owned by the U. S. Navy, and their operations are supported by the Office of Naval Research. The Office of Naval Research also supports part of the operations of the VEMA and HORIZON. The Navy is also providing one R5D aircraft for use in the Woods Hole Oceanographic Institution meteorological program and is supplying a NOMAD weather station. Support has been given to the National Oceanographic Data Center for research on data processing for the NOMAD buoy observations.

U. S. WEATHER BUREAU

INTERNATIONAL METEOROLOGICAL OBSERVATORY AT BOMBAY

The Weather Bureau has assigned two full-time meteorologists, Dr. Jose Colon and Mr. James Nicholson, to the International Meteorological Observatory at Bombay to participate in the meteorological program under the direction of Dr. Ramage. Mr. Nicholson entered on duty at Bombay on September 29, 1962, on a two-year assignment. Dr. Colon arrived on December 21, 1962, for a one-year tour of duty.

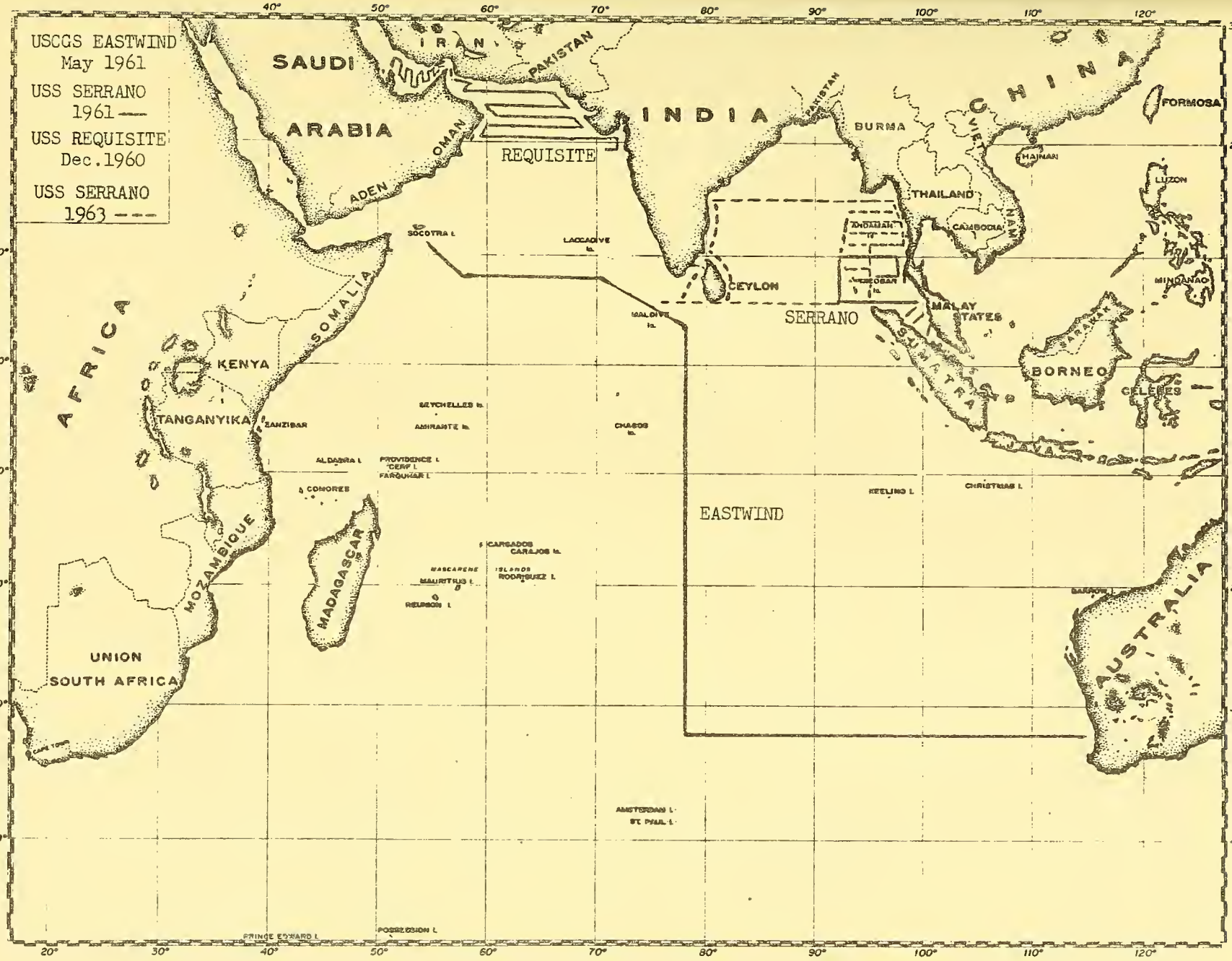

USCGS EASTWIND
May 1961
USS SERRANO
1961 ——
USS REQUISITE
Dec.1960
USS SERRANO
1963 - - -
SAUDI
ARABIA
IRAN
PAKISTAN
INDIA
CHINA
FORMOSA
BURMA
THAILAND
CAMBODIA
VIET NAM
HAINAN
LUZON
MINDANAO
OMAN
ADEN
REQUISITE
SOCOTRA I.
LACCADIVE
CEYLON
MALDIVE
SERRANO
MALAY STATES
SUMATRA
BORNEO
CELEBES
JAVA
AFRICA
SOMALIA
KENYA
TANGANYIKA
ZANZIBAR
SEYCHELLES
AMIRANTE
CHAGOS
ALDABRA I.
PROVIDENCE I.
FARQUHAR I.
COMORES
MOZAMBIQUE
MADAGASCAR
CARGADOS CARAJOS
MASCARENE ISLANDS
MAURITIUS I.
RODRIGUEZ I.
REUNION I.
KEELING I.
CHRISTMAS I.
EASTWIND
UNION SOUTH AFRICA
AUSTRALIA
AMSTERDAM I.
ST. PAUL I.
PRINCE EDWARD I.
POSSESSION I.

Figure 22

WEATHER BUREAU RESEARCH AIRCRAFT

The four Weather Bureau research aircraft arrived in Bombay on April 30, 1963 for a three-month period of gathering data needed to describe the onset of the Indian Ocean monsoon. They departed from Bombay on July 18, 1963. A second expedition of two aircraft in January to March, 1964 made similar measurements during the quiet season.

The Weather Bureau research aircraft consist of two DC-6A's, one W-57A, and one W-26. All are equipped with special meteorological probes and recorders for gathering meteorological data needed for research.

The two DC-6A/B aircraft (converted Douglas transports with four reciprocating engines) are equipped with Doppler navigation systems (APN-82) used to determine positions and automatically compute flight level winds. Temperatures are measured with the vortex thermometer (AMQ-8) and a high-response Rosemont probe. Humidity measurements are made by an infra-red hydrometer. D-values are determined from precision pressure transducers and radio altimeter systems. Three weather radar sets are installed -- a 10 cm radar for scanning at ranges up to 250 miles, a 5.6 cm nose radar with ranges up to 150 miles, and a vertical scanning radar operating flight conditions are recorded. Data is recorded digitally on magnetic tape with backup data recording photographically. Time lapse cameras record cloud forms.

The W-57 aircraft is a twin jet engine aircraft capable of operating up to 50,000 feet. The parameters recorded and methods of recording on this airplane are essentially the same as on the DC-6, except the humidity measurements are omitted and only one weather search radar operating on 3.2 cm is used.

The W-26 aircraft is a twin reciprocating engine airplane capable of operating up to altitudes of about 24,000 feet. A Doppler system is used for position determination, and the computation of flight level winds. Measurements of humidity, temperature, radar altitude and pressure altitude are made. Recording is made on a continuous strip by an oscillograph. A 5.6 cm weather radar is used and the scope is photographed.

The data collection program carried out by these aircraft during the three-month period was adjudged by all to be highly satisfactory. Large amounts of unique and essential data were accumulated, which are now being evaluated and processed at the International Meteorological Center at Bombay.

Among the highlights of the 1963 expedition are the following:

> On May 22nd and May 24th, the aircraft reconnoitered a tropical cyclone in the Arabian Sea which was the first aircraft reconnaissance of such a storm in that part of the world. Indian observers and photographers from USIS participated in these missions. A considerable amount of favorable publicity resulted and the missions may set the pattern for an Indian weather reconnaissance service.
>
> The RFF planes were displayed at Bangkok, Singapore, Nairobi, Gan, and finally on July 15th one of the DC-6's was inspected at New Delhi by Prime Minister Nehru and top members of his staff, who were also taken on a brief demonstration flight.

During the three-month period, while operating out of Bombay, the Weather Bureau research aircraft flew a total of 61 research missions involving 416 hours of flying time. Indian meteorologists and other visiting meteorologists accompanied many of the flights. There were more than 70 visiting meteorologists who participated. Enthusiastic and efficient aid from aviation authorities all over the region backed up the operation. The meteorological systems on board the aircraft functioned satisfactorily and no missions were aborted because of equipment failure. The data gathered by these aircraft are already proving invaluable in determining the meteorology of the Indian Ocean area and have resulted in revisions of previous concepts and the formulation of new ones.

On January 20, 1964, two DC-6's and 30 members of the RFF left their home base at Miami, Florida, to participate in the Meteorological Program of Phase II of the International Indian Ocean Expedition with their temporary base at Bombay, India.

Phase II of the IIOE was concerned primarily with the collection of meteorological data needed to study air/sea energy exchange and an extensive investigation of the general atmospheric circulation in the Indian Ocean area during the "winter monsoon."

During the six-week stay in India the two aircraft flew successful research missions, without a major failure of equipment or aircraft, totaling 337 hours and covering more than one hundred thousand miles. Flights were made to Gan, Mauritius, Cocos Island, Darwin, Singapore, Aden and numerous missions over the Indian Ocean and Arabian Sea.

The total mission was completed on March 5 and the planes stopped in Khartoum enroute to their home base at Miami, Florida.

WEATHER BUREAU MARINE PROGRAM

The meteorology program aboard the ANTON BRUUN was upgraded during the July, 1963 in-port period with the installation of a balloon inflation shelter and additional rawinsonde equipment. A complete surface synoptic and radiosonde program is now operational with Weather Bureau equipment and one meteorologist. Observations have been taken on all cruises in the Indian Ocean.

Meteorological observations are also being made on the cruises of ATLANTIS II, CONRAD, ARGO, and PIONEER.

BUREAU OF COMMERCIAL FISHERIES

The research program of the Bureau of Commercial Fisheries in the Indian Ocean has the following objectives:

1. To study the distribution and abundance of adult tunas in relation to the circulation during the two monsoon seasons.

2. To study the relation of the apex predators (tunas, marlins, sharks, etc.) to the food-chain, standing crops and productivity.

   a. Organisms eaten (qualitative and quantitative analyses of stomach contents).

   b. Standing crop of nekton (qualitative and quantitative analyses of mid-water trawl collections).

   c. Standing crop of zooplankton (qualitative and quantitative analyses of zooplankton collections).

   d. Phytoplankton productivity (C^{14} uptake).

3. Investigate subpopulations (seriology of apex predators: tunas, billfish, and sharks).

4. Distribution and abundance of larval and juvenile fish (plankton and night-light collections).

5. Zoogeography of zooplankton and zooplankton forms as biological indicators (distribution and abundance of selected zooplankters such as copepods of the genus Candacia).

6. Taxonomy, occurrence, and distribution of demersal fishes and invertebrates.

This program will be carried out by personnel of the Bureau's Biological Laboratory, Honolulu, aboard the ANTON BRUUN. On cruises 2 and 5, a party of 8 fishermen and 3 scientists will be embarked to engage in long-line fishing as follows:

a. On each cruise, fish 60 baskets of gear at each station. Occupy 16 stations along each of two meridians; 13 of the stations to be at 5° latitude intervals and remaining 3 stations to be occupied in areas of high abundance.

b. Data and biological samples to be collected.
   (1) Catch (by species) and effort.
   (2) Length and/or weight of each fish.
   (3) Sex and general state of maturation.
   (4) Preserve stomachs in 10 percent formalin.
   (5) Preserve ovaries in 10 percent formalin.
   (6) Preserve blood samples for seriological studies.
   (7) Preserve selected whole specimens for taxonomic studies.

Bottom trawling to study the distribution and relative abundance of demersal species in relation to the topography and nature of the bottom, will be conducted on cruises 1 and 4, using a single-warp shrimp trawl. Catches will be assessed quantitatively at sea, given a preliminary sorting, and sent to the U. S. National Museum for final distribution to qualified taxonomists for systematic studies of the fishes and invertebrates collected.

U. S. COAST AND GEODETIC SURVEY

GENERAL

The USC&GS ship PIONEER sailed from San Francisco on Tuesday, February 11, 1964, to take part in the International Indian Ocean Expedition. In the Malacca Straits, Andaman Sea, and Bay of Bengal, work was concentrated on geological-geophysical investigations of the regional submarine geology with special emphasis on detailed investigations of several submarine canyons. Three north-south profiles of oceanographic stations were made from 5°N to 5°S across the Equator south of the Bay of Bengal to tie in with the overall physical oceanographic investigations of the IIOE. Biological and meteorological observations are part of and in accord with the IIOE programs in biology and meteorology. Open house aboard the PIONEER for local officials, scientists, and the public was held at Calcutta, Colombo, and Djakarta. When possible, shipboard personnel delivered lectures at these ports to acquaint local scientists with the work of the expedition.

These plans were subject to slight modifications but reflected the PIONEER's program as it had developed over the past year. The plans for each leg of the expedition are discussed below. Dates of arrival and departure at Manila

and subsequent ports were subject to revision after the expedition had started.

LEG III - MANILA TO SINGAPORE

Left Manila March 13, arrived Singapore March 20.

Since no word had been received from scientists or officials at Jesselton, this previously planned stop had been eliminated. In addition to regular underway operations, two extra days of special investigations of the deep and rise northwest of North Borneo were scheduled. Details were worked out with Dr. Robert Burns (C&GS) and Dr. Robert Fisher (Scripps). The ARGO worked in this area in June 1962, and details of their work must be known before PIONEER's could be fully planned. At least one marine scientist from the Philippines was aboard to Singapore as an observer. One day of open house was held at Singapore.

Additional personnel:

Dr. Harris B. Stewart, Jr., C&GS
Dr. Robert E. Burns, C&GS
Geophysicist (gravity), C&GS
Mr. Kelvin S. Rodolfo, U. S. C.
Meteorologist, Weather Bureau
Meteorologist, Weather Bureau
Biologist, University of Hawaii
Biologist, University of Hawaii
Marine Scientist, Philippine Islands

LEG IV - SINGAPORE TO CALCUTTA

Leave Singapore March 24, arrive Calcutta April 20.

No word has been received from Mr. H. M. Jeremiah of the National SCOR Committee for Malaya (now Malaysia), but it is possible that one Malaysian scientist may be aboard on this leg.

On leaving Singapore the routine underway observations will be supplemented by routine sampling with the IIOE standard net in accordance with the IIOE Biological Program. In the Malacca Straits there will be a special program of sediment coring and - where practical - rock dredging. This program is planned to determine sediment and rock characteristics in those portions of the Straits not sampled by the Naval Oceanographic Office's work in this area. The detailed track in this area is being planned with Mr. George Keller (NOO) who will join the ship at Singapore specifically for this work in the Malacca Straits.

Profiles with the electrosonic profiler will be made at 5 knots in the Straits, the Andaman Sea, and the Bay of Bengal. This program, coupled with the sediment programs of Mr. Keller in the Straits and of Mr. Rodolfo in the Andaman Sea, and with the hydrographic, magnetic, gravity, heat probe, and camera operations, is directed toward providing data contributing to the solution of several specific problems. In the Straits, the intent is to check on features in a narrow strait which can be traceable to features on the bordering land. In this case it involves possible projection of the Malayan anticlines and synclines into the Straits, the possible extension of the large northeastern Sumatra sedimentary basin, and extension of a possible fault marking the eastward margin of the Andaman Sea basin. This fault is traceable to the Irrawaddy delta from northern Burma and marks the eastern limit of the Burmese oil basin. Sediment studies in the Irrawaddy delta are to determine the basinward variations in sediment characteristics, especially clay mineralogy, and for purposes of comparison with the Ganges delta. It is hoped to trace the continuation of the volcanic belt from the delta through the volcanic Narcondam and Barren Islands to the seaward extension of the Barisan Range of volcanoes of western Sumatra. This volcanic ridge at its northern end is covered by deltaic sediments but apparently is the inner volcanic arc of the island arc complex. This ridge will be investigated together with the parallel trough just east of the Andaman and Nicobar Islands. This trough is probably a northern continuation of the inner trough between Sumatra and the offshore islands to the west. At least two profiles will be made across the Andaman-Nicobar Ridge and into deep water to the west. These crossings will provide sediment samples to delineate the contract in sedimentary environment between the Andaman Sea and the open ocean. Rock dredging, bottom photography, electronsonic profiling, echo sounding, and gravity and magnetic measurements will all be utilized in attempting to understand the complex geology of the area.

Additional projects will include (1) dredging midway between North Andaman and the headland of the Arakan Range, where a few calcareous sandstone pebbles were recovered from grab samples taken by SERRANO in 1961. (2) Sediment sampling across the ridge foraminifera to correlate with the work of Schwager on samples off Car Nicobar Island taken by the Austrian frigate NOVARA in the last century, and (3) sediment sampling in the Gulf of Martaban to permit comparison between Irrawaddy sediments and those from the Sittang and Salween Rivers.

Delineation of the detailed trackline through the Straits of Malacca and Andaman Sea is not now possible. A tentative trackline will be available only after further discussions with Fisher of Scripps on the results of the ARGO's two crossings of the Andaman-Nicobar ridge in 1962. Three weeks are tentatively programmed for the Malacca Straits - Andaman Sea work, and the

actual tracklines throughout much of the area will of necessity be determined in the field on the basis of the results being obtained.

From the Andaman Sea, the PIONEER on about April 14 will move into the Bay of Bengal. Underway operations including tows with the IIOE standard net and standard IIOE meteorological observations will continue along 16°N to approximately 88°E, thence north to 18°N and east at least to the 100-fathom curve off the coast of Burma. By sawtooth legs along the slope west of the Burmese coastal islands, PIONEER will proceed northwest to 20°N. On this portion of the track, special attention will be paid to investigating the offshore continuation of structual features of the Arakan arc. Offshore basins are possibly the result of Tertiary or recent faulting. Dredge sampling will be made as appears practical. PIONEER on reaching 20°N will move west across the Ganges Canyon to 88°E, and from there direct to Calcutta.

Any topographic, magnetic, gravity, sub-surface structural or other anomaly found along these tracks will be investigated more fully as deemed practical by the Captain in consultation with the scientists concerned.

Special care will be taken along these east-west lines to look for any indications of the southerly extension of the Ganges Canyon. This feature has been surveyed in some detail by the Pakistan Navy as far as the edge of the continental shelf. Lines run by the GALATHEA showed it to extend beyond the shelf, but its southerly extent is unknown. It is possible that the valley found by the ALBATROSS east of Ceylon and the leveed channel reported by Knauss as having been crossed at the Equator at 87°E may be southerly continuations of this canyon.

At Calcutta the PIONEER will remain from April 20 to 28 for refueling, provisioning, some change of personnel, open house, and a series of lectures and meetings with local scientists. The U. S. Information Service at Calcutta reports that six institutions have already offered to cooperate -- the Geological Survey of India, Zoological Survey of India, Calcutta University, Jadavpur University, the Bose Institute, and the Association for the Cultivation of Science. Two days of scientific sessions will be planned in addition to open house on at least two days.

Additional personnel:

Dr. Harris B. Stewart, Jr., C&GS
Dr. Robert E. Burns, C&GS
Mr. Reginald Harbison (Electrosonic Profiler), C&GS
Mr. Austin Weeks (Electrosonic Profiler), C&GS
Mr. Byron Hale (deep-sea camera), C&GS

Additional personnel (Cont'd):

Geophysicst (gravity), C&GS
Mr. George Keller (sediments), NOO
Mr. Kelvin S. Rodolfo (sediments), U. S. C.
Meteorologist, Weather Bureau
Meteorologist, Weather Bureau
Biologist, University of Hawaii
Biologist, University of Hawaii
(?) Marine Scientist, Malaysia

LEG V - CALCUTTA TO COLOMBO

Leave Calcutta April 28, arrive Colombo May 19.

Standard underway operations will continue as before, but to them will be added special investigations of the Ganges delta and of the Ganges and Trincomalee submarine canyons. Dr. Robert S. Dietz (C&GS) and Dr. Francis P. Shepard of Scripps will board at Calcutta specifically for these studies. Leaving Calcutta, PIONEER will go directly to the Ganges delta. On two east-west lines across the delta, sediment samples will be taken and electrosonic profiles run in an attempt to compare this delta with the Irrawaddy delta. Where the latter delta seems to be building forward rapidly, the Ganges delta on the other hand, is advancing slowly. Following these sections, the ship will move to the Ganges Canyon at about 21°N, 89°E. By a series of crossings, the canyon will be followed south into the central Bay of Bengal. Sediment cores, dredge samples, electrosonic profiles, bottom photographs, and detailed development of features found by the standard underway measurements will be undertaken as decided upon in the field by the Captain in consultation with the scientists concerned. If this canyon terminates well north of the latitude of Ceylon, the east-west lines previously run in the eastern Bay of Bengal shall be continued westward from 88°E to the coast of India. In this event, it might be possible to investigate in detail Krisna, Mahadevon, and Andhra submarine canyons (17° 54'N, 84° 16'E to 17° 44'N, 84° 02'E) discovered earlier in the IIOE.

Upon reaching the southern termination of the Ganges Canyon or after completing the east-west lines, PIONEER will head for Trincomalee on the northeast coast of Ceylon. N. O. charts 2523 and 3689 show hard ridges through which has been cut a submarine canyon that heads in Trincomalee and Goddiyar Bays. The canyon has apparently been cut in quartzite and other head Pre-Cambrian rocks and extends seaward to depths of at least 800 fathoms where the existing sounding terminate.

In shallow depths, divers will investigate the canyon head using SCUBA gear. All equipment which can provide data on this canyon will be utilized in an investigation of which the details will be planned in the field by the Captain in consultation with Drs. Shepard, Dietz, Stewart, and Burns.

Following this canyon study, the ship will go directly to Colombo for fuel, resupply, and open house. It is possible that one marine scientist from India and one from Ceylon will take part on the leg from Calcutta to Colombo. At Colombo all plankton samples collected with the IIOE standard net will be forwarded together with the location of each sample to the Indian Ocean Biological Center, CSIR, University Oceanographic Laboratories, Ernakulam, Cochin, India. The official IIOE stencil should be used on all such shipments. At Cochin, determination will be made of displacement volume, and sorting will be accomplished for distribution to specialists in the various zooplankton groups.

Additional personnel:

Dr. Harris B. Stewart, Jr., C&GS
Dr. Robert S. Dietz, C&GS
Geophysicist (gravity), C&GS
Mr. Austin Weeks, C&GS
Mr. Reginald Harbison, C&GS
Mr. Byron Hale (deep-sea camera), C&GS
Dr. Francis P. Shepard, SIO
Mr. Kelvin S. Rodolfo, U. S. C.
Meteorologist, Weather Bureau
Meteorologist, Weather Bureau
Biologist, University of Hawaii
Biologist, University of Hawaii
Marine Scientist, India
Marine Scientist, Ceylon

LEG VI - COLOMBO TO DJARKARTA

Leave Colombo May 25, arrive Djarkarta June 23.

If the southern limits of the Ganges Canyon were not found prior to the work in Trincomalee Canyon, the Ganges Canyon investigation will be continued southward until the terminus is reached. Otherwise PIONEER will go directly to 5°N, 84°E to start the first of three north-south profiles of oceanographic stations from 5°N to 5°south along 84°E, and 92°E. Standard underway practical-between stations and between profiles. Oceanographic stations will be occupied for temperature, salinity, dissolved oxygen and phosphate along each profile at 5°, 4°, and 3°, and at 1/2 degree intervals to the Equator for a total of

17 stations along each profile. The stations at 5°, 3°, and 1°N and S will be deep stations to the bottom, the others will be to 2,000 meters. After the station at the equator and 92°E, the ship will move due west to 90°E. The IIOE has designated 0° at 90°E as a standard station to be occupied by all ships in the area. At this point an oceanographic station will be observed to 2,000 meters with bottles at standard depths. The ship will then return to the profile at 0° 30'S, 92°E and continue station observations as planned. Work done on the LUSIAD expedition under Dr. Knauss showed that the salinity structure in the region of the thermocline necessitated a 10-meter bottle spacing in that region for adequate definition. For this reason it is planned that PIONEER will use 36 bottles between the surface and 1,200 meters at the nine stations between 2°N and 2°S. Bottle spacing below 1,200 meters will be at standard depths.

Upon completion of these three sections of oceanographic stations PIONEER will make three crossings of the northwestward extension of the trend of the Java Trench. The first will be from 5°S, 92°E to Sumatra in the general area of Padang (1°S, 100° 30'E), from thence SSW across the trend to the latitude of the Sunda Strait, thence due east through the Sunda Strait to Djakarta. The purpose of these profiles is to determine the features of the inner and outer troughs on opposite sides of the Mentawai Island chain. Supplementing the standard underway investigations will be heat probe, dredging, coring, deep-sea camera, and electrosonic profile studies as deemed worthwhile by the Captain in consultation with the pertinent scientists.

Upon arrival at Djakarta, open house will be held aboard PIONEER and local lectures will be arranged through USIA. In addition, a one-day trip out of Djakarta will be planned to acquaint Indonesian scientists with the work of the PIONEER. The number of guest scientists that can be accommodated will be determined by the Captain. A one-day trip to Krakatoa and the eastern flank of the Java Trench is tentatively planned. At Djakarta those biological samples obtained with the IIOE standard net will be shipped to the Indian Ocean Biological Center at Cochin, India.

Additional Personnel:

Geophysicst (ESP), C&GS
Geophysicist (gravity), C&GS
Mr. Ronald K. Reed (Oceanographer), C&GS
Mr. Richard B. Perry (Geological Oceanographer), C&GS
Oceanographer, C&GS
Oceanographer, C&GS
Mr. Mark Schuldt (Deep-sea camera), C&GS
Mr. Kelvin S. Rodolfo, U. S. C.
Meteorologist, Weather Bureau
Meteorologist, Weather Bureau

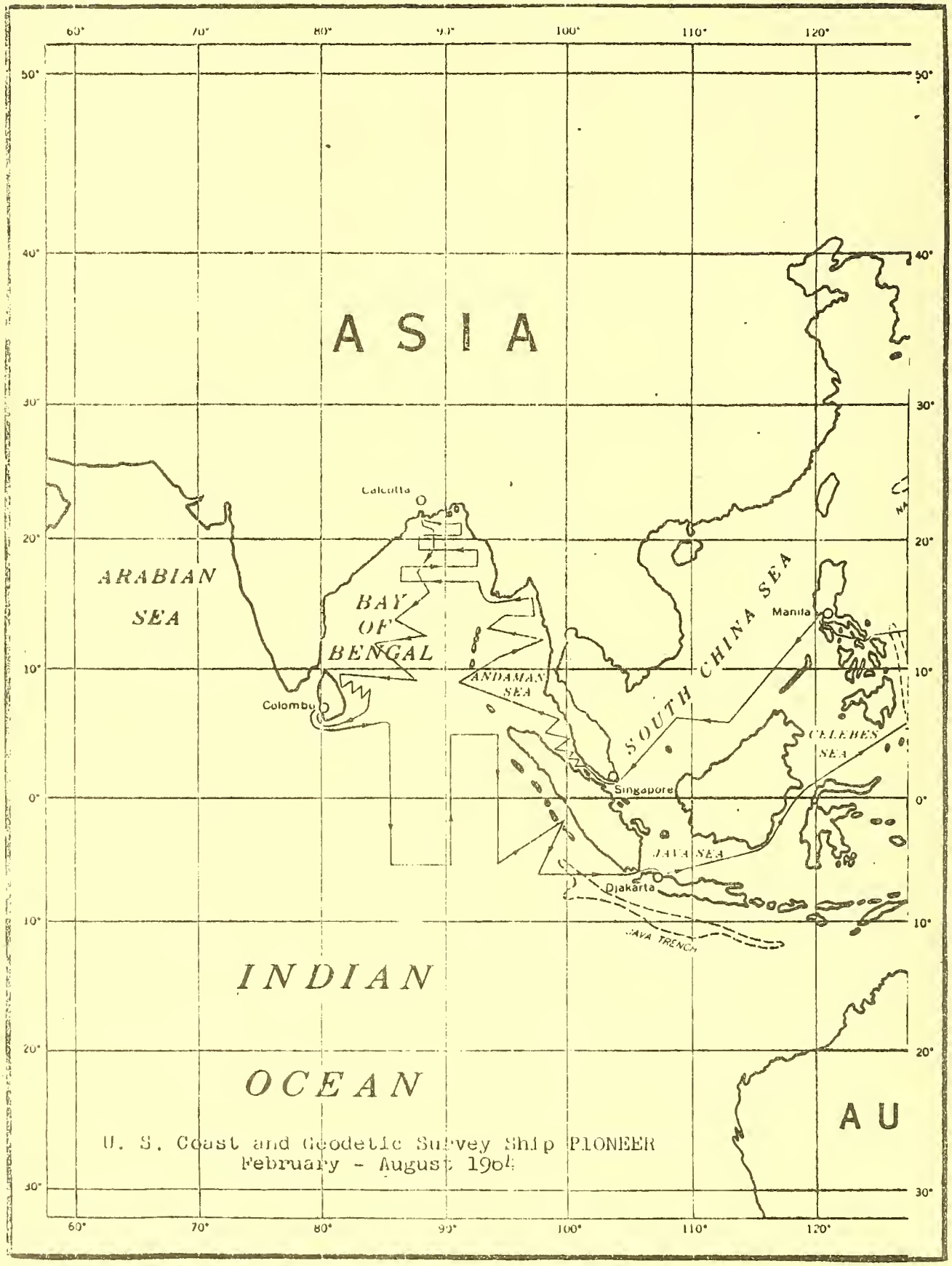

ASIA
ARABIAN SEA
BAY OF BENGAL
ANDAMAN SEA
SOUTH CHINA SEA
CELEBES SEA
JAVA SEA
JAVA TRENCH
INDIAN OCEAN
AU
Calcutta
Colombo
Manila
Singapore
Djakarta
60°
70°
80°
90°
100°
110°
120°
50°
40°
30°
20°
10°
0°
10°
20°
30°
U. S. Coast and Geodetic Survey Ship PIONEER
February - August 1964

Figure 21

Additional Personnel (Cont'd):

Biologist, University of Hawaii
Biologist, University of Hawaii

NATIONAL SCIENCE FOUNDATION

Support of the United States program for the IIOE by the National Science Foundation is epitomized by the following tabulation of grants made since 1960:

NSF Grant No.	Institution	Principal Investigator	Title	Amount
G-11800	National Academy of Sciences - National Research Council	R. C. Vetter	Support to the Special Committee on Oceanic Research of the International Council of Scientific Unions	$ 47,400
G-16570	National Academy of Sciences - National Research Council	G. D. Meid	Support of Coordinator, Indian Ocean Expedition	46,900
G-16570A1 A2	National Academy of Sciences - National Research Council	L. Hoover	Support of Coordinator, Indian Ocean Expedition	44,200 19,300
G-17182	Woods Hole Oceanographic Institution	J. H. Ryther	Planning of a Program in Biology for the Indian Ocean Expedition	24,000
G-19289	University of Hawaii	C. S. Ramage	Support of U. S. Meteorology Program of the Indian Ocean Expedition	97,200
G-20952 Amen. 1 Amen. 2 Amen. 3 C-282 Amen. 1 Amen. 2 Amen. 3	Woods Hole Oceanographic Institution	J. H. Ryther	U. S. Program in Biology for the IIOE	450,000 271,600 300,000 150,000 500,000 425,000 14,000

NSF Grant No.	Institution	Principal Investigator	Title	Amount
G-21960	University of Rhode Island	J. A. Knauss	Equatorial Circulation of the Indian Ocean	$100,000
G-22223	Office of Naval Research	J. Hughes	NOMAD Weather Station for the IIOE	50,000
G-22255 Amen. 1 Amen. 2	University of California	R. L. Fisher	Participation in IIOE	150,000 680,300 285,600
G-22260 Amen. 1	Columbia University	M. Ewing	Participation in the IIOE	150,000 544,200
G-22388 Amen. 1	University of Michigan	D. J. Portman	Heat and Water Vapor Exchange for the IIOE	231,900 86,500
G-22389 Amen. 1 Amen. 2	Woods Hole Oceanographic Institution	A. F. Bunker	Air-Sea Interaction for the IIOE	97,000 110,720 178,000
G-22413 Amen. 1 Amen. 2	University of Hawaii	C. S. Ramage	Atmospheric Circulation Project for the IIOE	146,600 181,800 200,400
G-25115	Woods Hole Oceanographic Institution	A. F. Bunker	Research Aircraft for Meteorological Program of the IIOE	100,000
GP-465	U. S. Air Force	E. J. Timberlake	Research Meteorologists for the IIOE	60,000
GP-571	University of Washington	R. G. Fleagle	Comprehensive Study of Energy Transfer Near the Earth's Surface	140,000
GP-576 Amen. 1	U. S. Weather Bureau	F. W. Reichelderfer	Meteorological Research Utilizing U. S. Weather Bureau Aircraft	490,980 201,500

NSF Grant No.	Institution	Principal Investigator	Title	Amount
C-298 Amen. 1 Amen. 2	Alpine Geophysical Assoc., Inc.	W. C. Beckmann	Operation and Maintenance of the Research Vessel	$ 600,000 316,000 507,000
GP-821 Amen. 1	Woods Hole Oceanographic Institution	P. Fye	Studies in the Indian Ocean	150,000 1,100,400
G-17465 Amen. 2	Stanford University	R. Bolin	Operation of Research Vessel TE VEGA	529,100
GP-2233	University of Hawaii	C. S. Ramage	Automatic Picture Taking Ground Equipment for Satellite Observations	60,000
GP-2270	University of Washington	F. Badgley	Comprehensive Study of Energy Transfer Near the Earth's Surface	84,500
GP-2418	University of Washington	F. Badgley	Energy Transfer Near the Earth's Surface	137,600
GP-2370	Woods Hole	J. G. Hersey	Indian Ocean Expedition	654,000

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UNITED STATES PARTICIPATION

in the

INTERNATIONAL COOPERATIVE INVESTIGATIONS OF THE TROPICAL ATLANTIC

by

T.S. Austin
International Coordinator
Revised April, 1964

A. ORGANIZATION AND HISTORY

The International Cooperative Investigations of the Tropical Atlantic (ICITA) evolved from a proposal by the Commission for Technical Cooperation in Africa (CCTA) to conduct trawling investigations in West African waters from the mouth of the Congo River north to Dakar, Senegal. Early in 1961 the Bureau of Commercial Fisheries proposed that the Bureau cooperate with CCTA by making a study of the pelagic areas of the Gulf of Guinea. The interest of other oceanographic and fishery research organizations in this area and in adjacent areas of the Tropical Atlantic led to a meeting in February 1962 of representatives from various United States, Argentine, and Brazilian activities. A plan for a multiple vessel investigation of the Tropical Atlantic was developed at that meeting and subsequently presented to the Intergovernmental Oceanographic Commission for consideration as an international effort. In June 1962 representatives from 17 member nations met in Washington D.C. to prepare detailed plans and schedules for the ICITA. Approved and formally adopted by the Second Session of the IOC in September 1962, the ICITA program consisted of a mid-winter (EQUALANT I) and a mid-summer (EQUALANT II) multiple-vessel survey of the Tropical Atlantic, 18°N to 18°S. latitudes between the coasts of Africa and South America.

EQUALANT I (February-April 1963)

Fourteen vessels from seven nations participated in EQUALANT I:

Argentina - COMODORO AUGUSTO LASERRE

Brazil - BAEPENDI and BERTIOGA

Congo (Brazzaville) - OMBANGO

Nigeria - KIARA

Republic of Ivory Coast - REINE POKOU

United States - CHAIN and CRAWFORD (WHOI); EXPLORER (USC&GS); OREGON (BCF)

Figures 1 and 2 show composite track charts with locations of oceanographic and biological stations.

EQUALANT II (August-September 1963)

Eleven vessels from eight nations participated during EQUALANT II:

Argentina - COMODORO AUGUSTO LASERRE

Brazil - BRACUI

Congo (Brazzaville) - OBANGO

Nigeria - ENUGU

Republic of Ivory Coast - REINE POKOU

Spain - MALASPINA

United States - PILLSBURY (Miami); CASCO (USCG) GERONIMO (BCF)

USSR - MIKHAIL LOMONOSCOV; ZVESDA

Figures 3 and 4 show composite track charts with locations of oceanographic and biological stations made during EQUALANT II.

EQUALANT III (February-March 1964)

EQUALANT III was proposed in July 1963 by members of the International Coordination Group (ICG) for the International Cooperative Investigations of the Tropical Atlantic and subsequently approved by the Bureau and Consultative Committee of the IOC. Direct current measurements, accompanied by classifical oceanographic and marine biological observations were made in an area from 10°N to 10°S latitudes, and 30°W longitude east to the coast of Africa. (Figure 5).

Eight vessels from six nations participated in EQUALANT III:

Congo (Brazzaville) - OBANGO

Ghana - SAKUMO

Republic of Ivory Coast - REINE POKOU

Spain - MALASPINA

USA - GERONIMO (BCF); PILLSBURY (Miami)

USSR - MIKHAIL LOMONOSOV; ZVEZDA

During all three phases of the International Cooperative Investigations of the Tropical Atlantic, scientists from the international oceanographic community were invited to participate. Scientists from Germany, England and Venezuela as well as from various federal, university and private organizations worked from several of the above mentioned vessels.

B. SCIENTIFIC PROGRAM

The observational and sampling programs common to each vessel participating included serial casts to an assured depth of 2000 meters. Bottom casts were made every 120 miles from vessels with the capability. Measurements of temperature, salinity, oxygen and inorganic phosphate were made at each depth sampled. Bathythermograph lowerings were made every 30 miles. Daily measurements were made of primary productivity using the C-14 technique. Also measured daily was the microbiomass at the surface and at depths of 50,20, and 10 meters and of that depth receiving one percent of incident radiation. A zooplankton tow was made once each night, oblique to the top of the thermocline. Routine meterological observations were made at the time of each BT and at 0000, 0600, 1200 and 1800 hours daily. Plans for various special types of observations aboard one or more of the participating vessels included upper air meterological data by U.W. Weather Bureau Observers. The Weather Bureau's Weather Satellite Center made sea surface ratiation measurements, special cloud observations and photographs. Direct current measurements were made by means of instrumented buoy arrangs anchored from CHAIN(WHOI) and from the Soviet vessel LOMONOSOV, and with drogues operated from the U.S. Coast and Geodetic Survey ship EXPLORER.

A Data Report for EQUALANT I has been compiled by the National Oceanographic Data Center and printed by the Coast and Geodetic Survey. The Data Report for EQUALANT II is scheduled for publication in late summer 1964. There are, at present, no plans for preparation and publication of an EQUALANT III Data Report.

A proposal for preparation of ICITA Atlases was prepared by NODC and the International Coordinator. This was subsequently reviewed, revised and approved by the International Coordination Group. Methods for funding preparation and publication of the Atlases were discussed at the June 1964 meeting of the ICG.

C. PARTICIPATING U. S. AGENCIES AND INSTITUTIONS

The success of the ICITA can be attributed in large measure to the participation, cooperation and assistance of a number of federal agencies, universities and government supported oceanographic institutions. Published and planned Data Reports give detailed information on the activities of ICITA participants. Below is a brief summary.

1. U.S. Naval Oceanographic Office

Assistance in preparing and printing a compilation of oceanographic charts for the waters of the Tropical Atlantic; preparation of salinity substandards for intercalibration purposes and loan of various pieces of oceanographic equipment.

2. National Oceanographic Data Center

Assembly and mailing of log forms, plotting sheets and standard instructions; preparation and publication of the ICITA Data Reports.

3. Coast and Geodetic Survey

Assignment of EXPLORER to EQUALANT I; Radio Central aboard the EXPLORER; preparation of plotting sheets and drift cards for use aboard each vessel; compilation of tide data for inclusion in Data Reports. Scientists and observers from New York University, U.S. Weather Bureau and Kiel University participated aboard the EXPLORER.

4. Weather Bureau

Observers assigned to various vessels for surface and upper air meteorological observations; daily forecasts prepared and transmitted for use aboard each vessel; infra red sensors supplied various vessels for measurements at sea surface; special reporting forms supplied to each vessel; for cloud observations (for use with TIROS data); preparation of data for publication in ICITA Data Reports.

5. Coast Guard

Assignment of CASCO to EQUALANT II; Radio Central aboard CASCO; daily transmission of data from one oceanographic station to National Oceanographic Data Center for quality control experiment (as from the Argentine vessel COMODORO AUGUSTO LASERRE). Scientists, observers and technicians from Johns Hopkins, New York University, U. S. Naval Oceanographic Office, U. S. Weather Bureau, University of Kiel, Germany and National Oceanographic Data Center participated aboard the CASCO.

6. Atomic Energy Committee, Office of Naval Research and National Science Foundation

Financial support to various U. S. participants in EQUALANTS I, II and III. Atomic Energy Committee provided funds for C-14 and plankton equipment and supplies used on board each participating vessel.

7. Bureau of Commercial Fisheries

Assignment of the OREGON to EQUALANT I and of the GERONIMO to EQUALANTS II and III; services of a Bureau employee as International Coordinator; determination of counts for C-14 (BCF Radiobiological Laboratory) and of displacement volumes of zooplankton samples; scientists; procurement and shipment of all C-14 and plankton supplies and equipment. Observers and technicians from Kiel University, National Oceanographic Data Center, Commission for Technical Cooperation in Africa, Virginia Institute of Marine Science and the ORSTOM Laboratory at Pointe-Noire, Congo (Brazzaville) participated on board the GERONIMO.

8. National Aeronautics and Space Administration

Transmission of routine messages from the GERONIMO through the MSTS KINGSPORT (anchored in Lagos). Subsequent to the period of EQUALANT II, but during the period of operation from the GERONIMO in the Gulf of Guinea, the data (depth, temperature and salinity) from a 1000 meter oceanographic station were sent to National Oceanographic Data Center via the Syncom II satellite. These data were subjected to a quality control analyses by National Oceanographic Data Center and the quality control message transmitted to the

GERONIMO. The entire procedure, GERONIMO to KINGSPORT through the satellite to National Oceanographic Data Center and back to the GERONIMO, was completed in approximately one half hour. With proper teletype circuits, and with computers available at the quality control center, "raw" observed data could be transmitted through the satellite; fully processed data plus results of quality control analyses could be provided to the vessel within a very short period of time. Such data, considered both ashore and on board the vessel, would provide a reliable base for revisions of cruise plans and schedules if "atypical" situations were observed or were noted to be in the process of developing.

9. State Department

Clearances for U. S. government vessels to enter foreign ports; translations of standard instructions into French, Spanish and Russian and expediting passport and visa requirements for scientists aboard the participating vessels.

10. Smithsonian Institution

The Smithsonian's Oceanographic Sorting Center sorted all zooplankton and night light samples from EQUALANTS I, II and III.

11. Woods Hole Oceanographic Institution

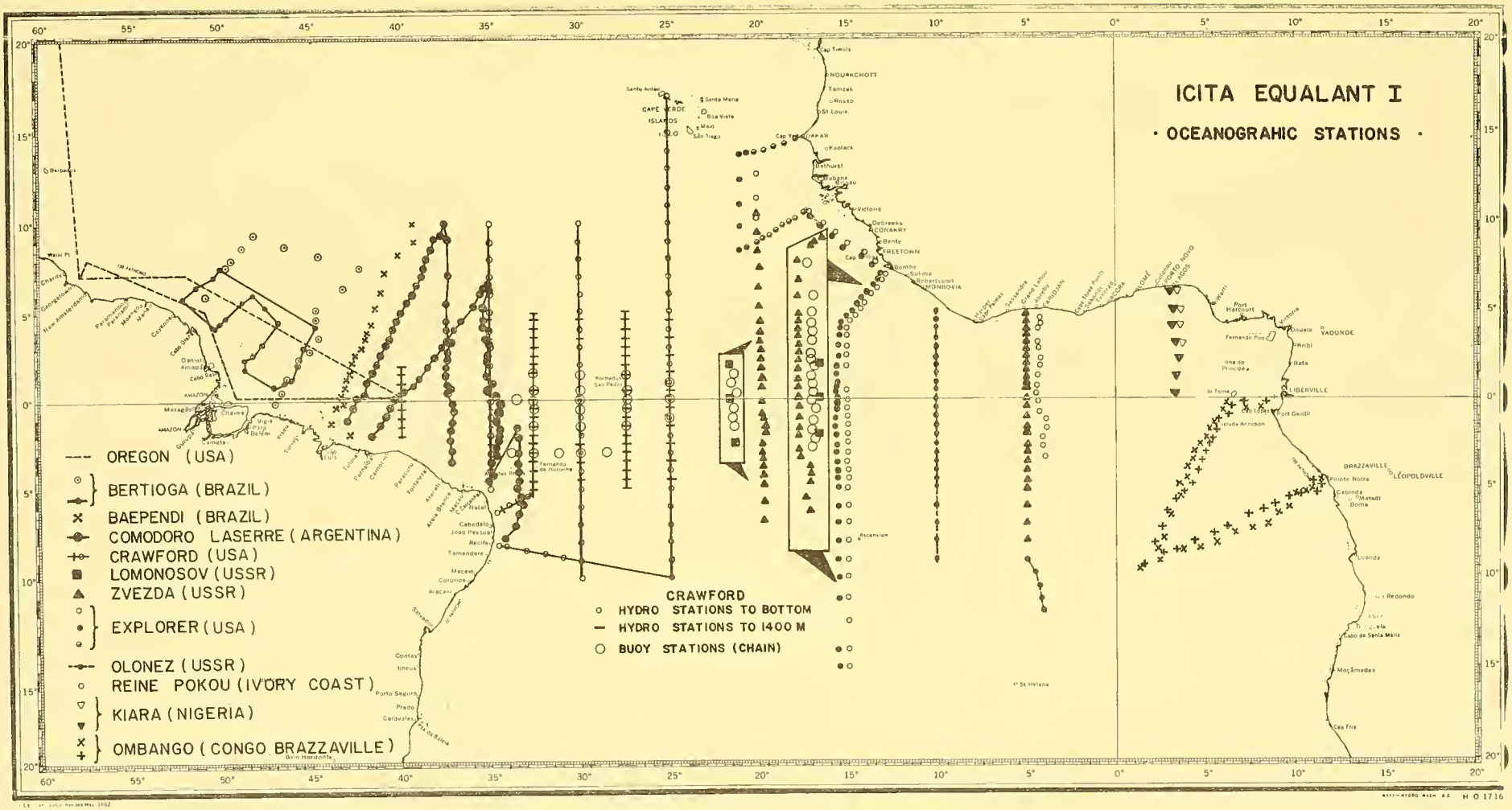
Participation of CHAIN and CRAWFORD in EQUALANT I. Assistance with procurement of C-14 incubators and plankton nets used aboard each vessel.

12. University of Miami

Participation of PILLSBURY in EQUALANTS II and III.

13. Texas A & M

Oceanographers aboard the COMODORO AUGUSTO LASERRE (Argentina) during EQUALANTS I and II; processed all data from both cruises.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· OCEANOGRAHIC STATIONS ·
OREGON (USA)
BERTIOGA (BRAZIL)
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COMODORO LASERRE (ARGENTINA)
CRAWFORD (USA)
LOMONOSOV (USSR)
ZVEZDA (USSR)
EXPLORER (USA)
OLONEZ (USSR)
REINE POKOU (IVORY COAST)
KIARA (NIGERIA)
OMBANGO (CONGO BRAZZAVILLE)
CRAWFORD
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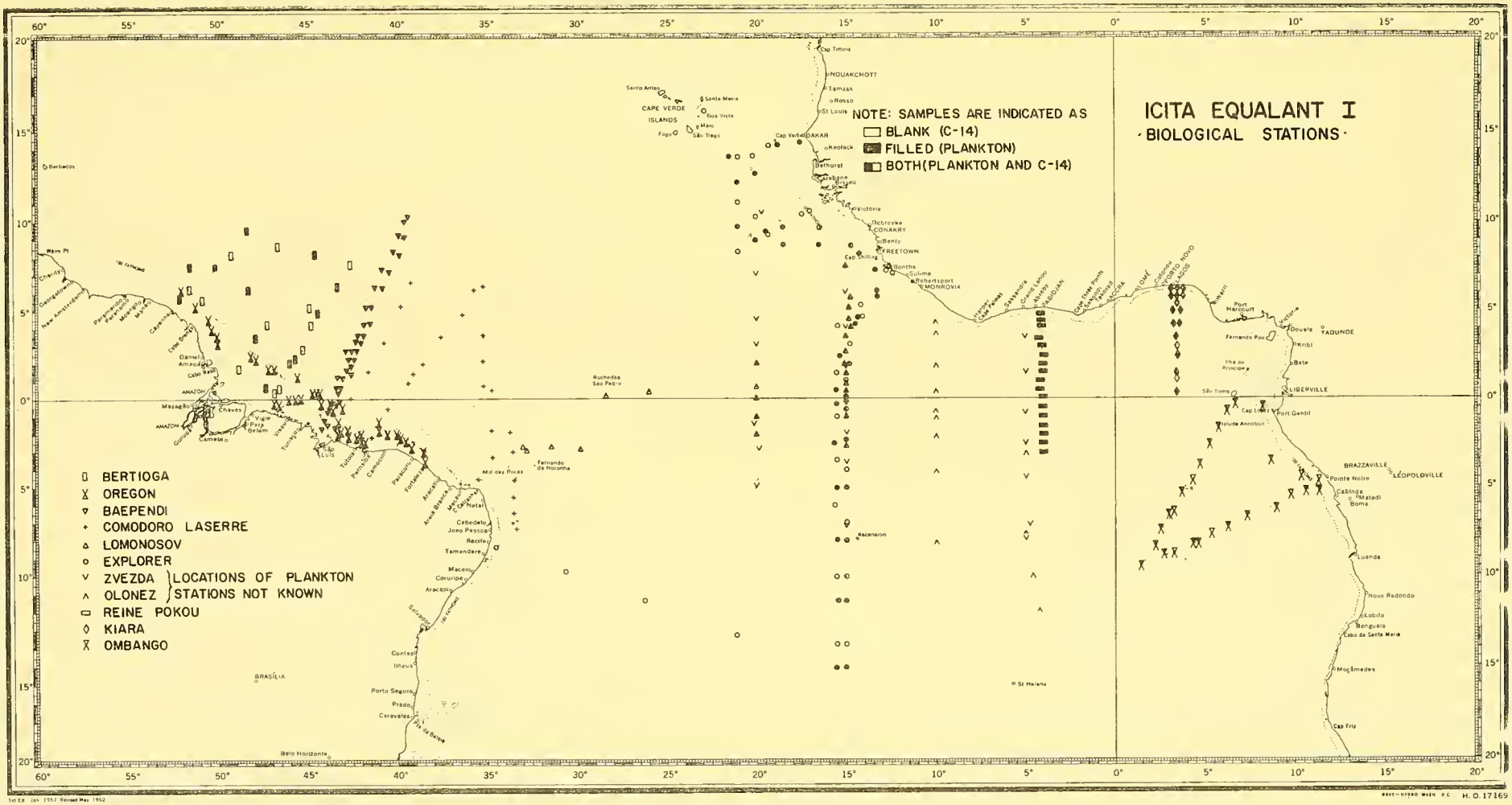
HYDRO STATIONS TO 1400 M
BUOY STATIONS (CHAIN)
H O 1716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NOTE: SAMPLES ARE INDICATED AS
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FILLED (PLANKTON)
BOTH (PLANKTON AND C-14)
BERTIOGA
OREGON
BAEPENDI
COMODORO LASERRE
LOMONOSOV
EXPLORER
ZVEZDA
OLONEZ
LOCATIONS OF PLANKTON STATIONS NOT KNOWN
REINE POKOU
KIARA
OMBANGO
CAPE VERDE ISLANDS
NOUAKCHOTT
DAKAR
CONAKRY
FREETOWN
MONROVIA
ABIDJAN
ACCRA
LOMÉ
PORTO NOVO
LAGOS
YAOUNDE
LIBERVILLE
BRAZZAVILLE
LEOPOLDVILLE
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Fernando de Noronha
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Belo Horizonte
Cap Frio
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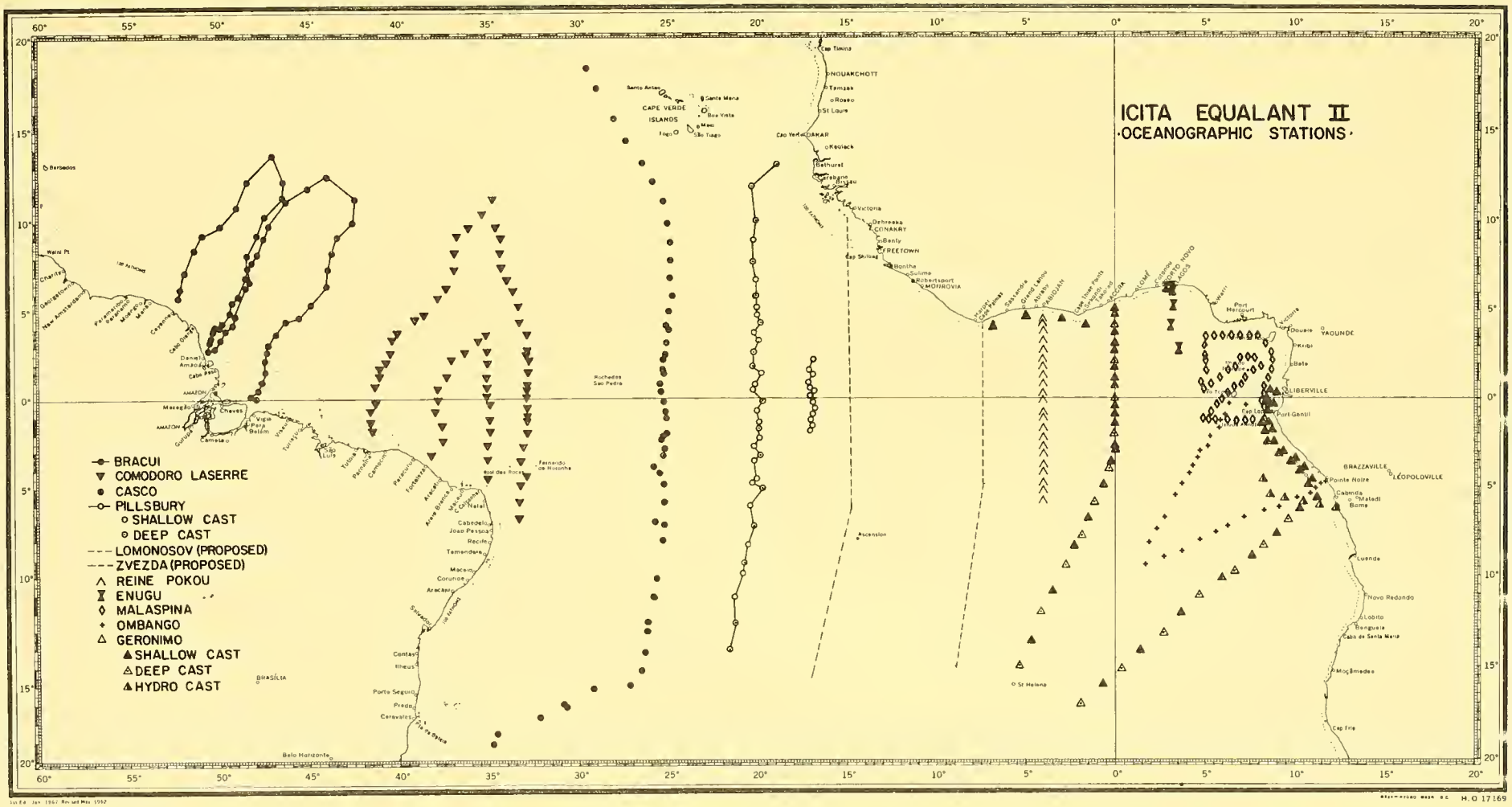
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·OCEANOGRAPHIC STATIONS·
BRACUI
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CASCO
PILLSBURY
SHALLOW CAST
DEEP CAST
LOMONOSOV (PROPOSED)
ZVEZDA (PROPOSED)
REINE POKOU
ENUGU
MALASPINA
OMBANGO
GERONIMO
SHALLOW CAST
DEEP CAST
HYDRO CAST
CAPE VERDE ISLANDS
NOUAKCHOTT
DAKAR
CONAKRY
FREETOWN
MONROVIA
ABIDJAN
ACCRA
LOMÉ
PORTO NOVO
LAGOS
YAOUNDE
LIBERVILLE
BRAZZAVILLE
LÉOPOLDVILLE
Port Gentil
Pointe Noire
Luanda
Novo Redondo
Lobito
Benguela
Moçâmedes
Cap Frio
Ascension
St Helena
Rochedos São Pedro
Fernando de Noronha
Belo Horizonte
BRASÍLIA
Cabedelo
Joao Pessoa
Recife
Tamandaré
Maceio
Coruripe
Aracaju
Salvador
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Porto Seguro
Prado
Caravelas
Belém
Cameta
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Waini Pt
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Georgetown
New Amsterdam
Paramaribo
Belem
Cabo Desejo
Daniel
Amazon
Cabo Paso
Vigia
Para
Belém
Viseu
Turiaçu
São Luís
Tutoia
Parnaíba
Camocim
Paracuru
Fortaleza
Aracati
Areia Branca
Macau
Natal
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St Louis
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Victoria
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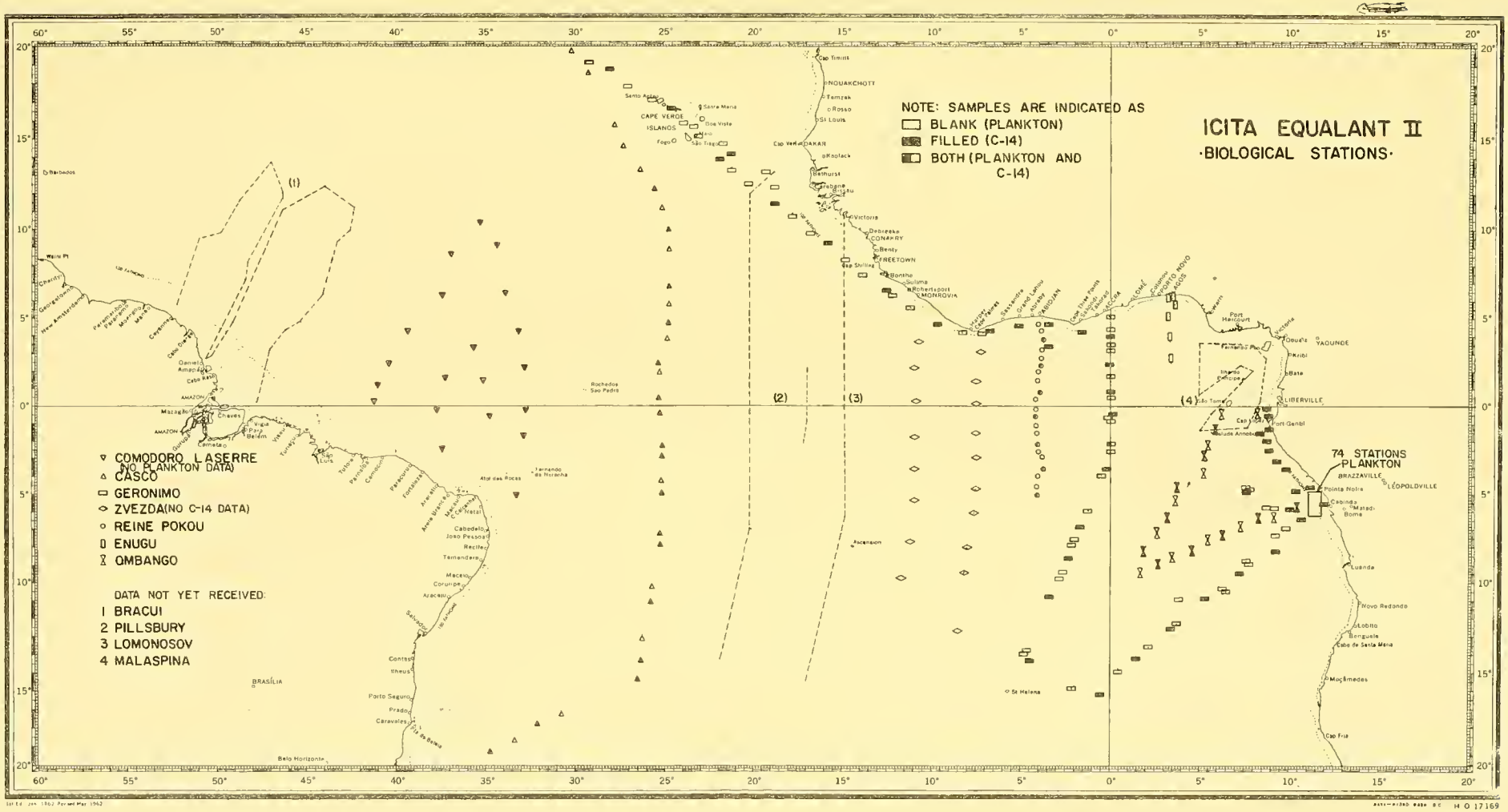
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·BIOLOGICAL STATIONS·
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BOTH (PLANKTON AND C-14)
74 STATIONS PLANKTON
COMODORO LASERRE (NO PLANKTON DATA)
CASCO
GERONIMO
ZVEZDA (NO C-14 DATA)
REINE POKOU
ENUGU
OMBANGO
DATA NOT YET RECEIVED:
1 BRACUI
2 PILLSBURY
3 LOMONOSOV
4 MALASPINA
(1)
(2)
(3)
(4)
CAPE VERDE ISLANDS
DAKAR
NOUAKCHOTT
FREETOWN
MONROVIA
ABIDJAN
LIBERVILLE
BRAZZAVILLE
LÉOPOLDVILLE
YAOUNDE
BRASÍLIA
Belo Horizonte
Salvador
Recife
Fernando de Noronha
Atol das Rocas
Rocheds São Pedro
Ascension
St Helena
Luanda
Lobito
Benguela
Moçâmedes
Cap Frio
Port Harcourt
Port-Gentil
Pointa Noire
Belém
Manaus
Barbados
Cayenne
Paramaribo
Georgetown
Freetown
Bathurst
Dakar
Cap Vert
Cap Timiris
Santa Maria
Dias Viste
São Tiago
Fogo
Santo Antão
Tamzak
Rosso
St Louis
Kaolack
Victoria
Debreeka
Bonthe
Sulima
Robertsport
Sassandra
Grand Lahou
Abidjan
Cape Three Points
Takoradi
Accra
Lomé
Cotonou
Porto Novo
Lagos
Warri
Douala
Kribi
Bata
Ilha de Príncipe
São Tomé
Cap Lopez
Luanda
Cabinda
Matadi
Boma
Belém
Manaus
Macapá
Fortaleza
Natal
Cabedelo
João Pessoa
Maceió
Aracaju
Salvador
Ilhéus
Porto Seguro
Prado
Caravelas
Vitória
Rio de Janeiro
Santos
Paranaguá
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Rio Grande
Cananéia
Iguape
Ilha Grande
Cabo Frio
Cabo Raso
Cayenne
Paramaribo
Georgetown
Nova Amsterdam
Mazagão
Chaves
Viga
Para
Belém
Cametá
Ourém
Vizeu
Turiaçu
São Luís
Tutóia
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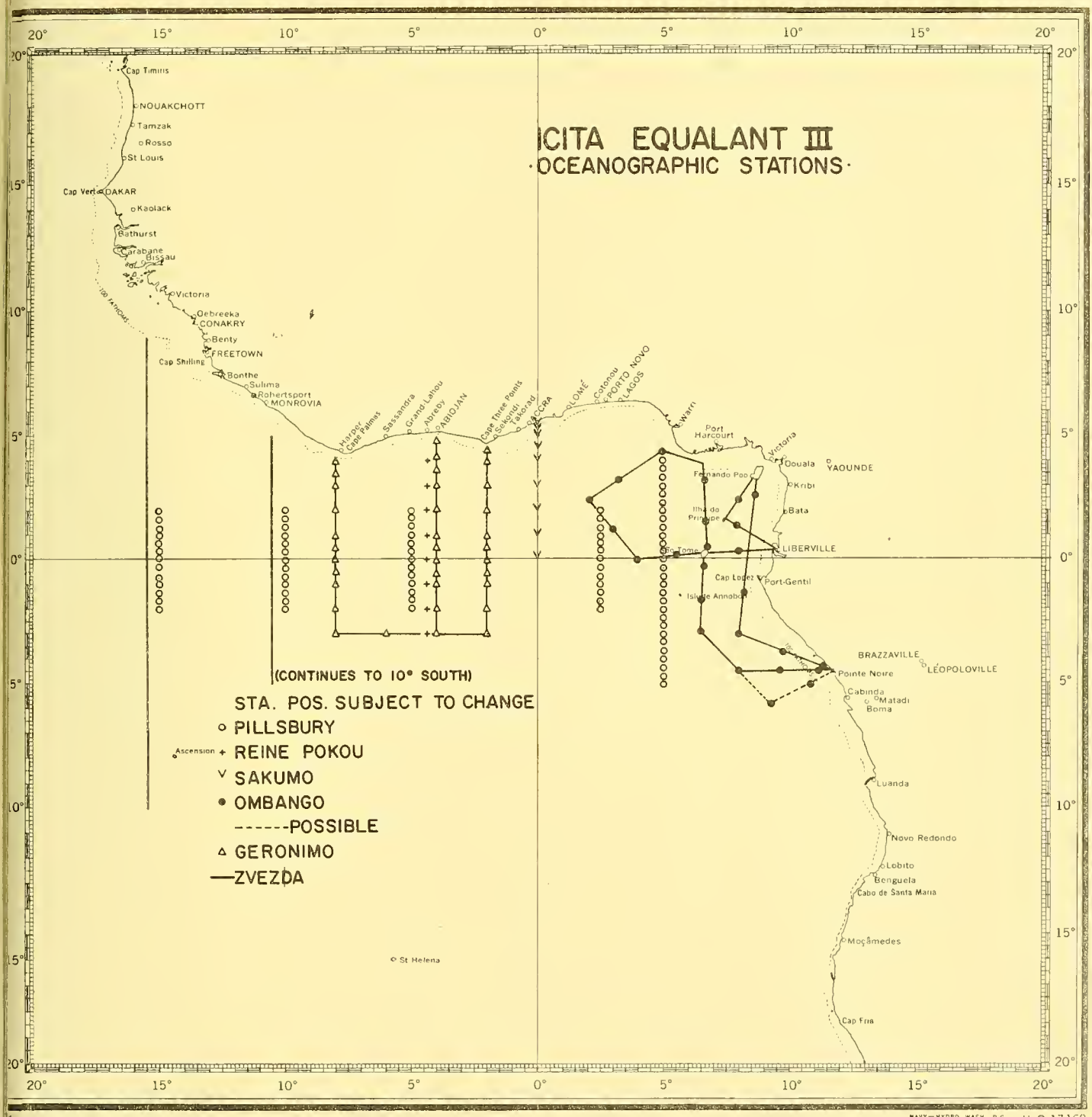

NAVY—HYDRO WASH D C H O 17169

Distribution List:

ASN (R&D)
ONR
  Codes 410, 414, 416, 418
BuShips
  Code 373A (for BuShips laboratories)
BuWeps
  Code RU222 (for BuWeps laboratories)
BuDocks (for NCEL)
CNO
  OP 71
  OP 09B5
NRL
NTDC

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INTERAGENCY COMMITTEE ON OCEANOGRAPHY

ICO:RBA:sds

: AUG 19

MEMORANDUM

From: ICO Secretary
To: Distribution List

Subj: Operational Report of the International Indian Ocean Expedition and International Cooperative Investigation of the Tropic Atlantic; forwarding of

Encl: (1) Subject report

1. As you know it has been customary each year for the Interagency Committee on Oceanography to include as part of the National Oceanographic Program document for each Fiscal Year, progress reports on the International Indian Ocean Expedition and the International Cooperative Investigation of the Tropical Atlantic.

2. This year, owing to lack of time and space, it was impossible to incorporate these reports within the document itself. Accordingly, they are being issued as informal supplements to the Fiscal Year 1965 National Oceanographic Program report.

3. Additional copies may be obtained from the ICO Staff.

Robert B. Abel

ROBERT B. ABEL